

**Issues on Regional
Development Problems
in Darfur
and the Red Sea
Regions**

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اسم الكتاب

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Introduction

The Sudan faces many regional development problems that threaten its future as a unified state. This book explores some of these problems in the two regions of Darfur and the Red Sea. There are issues focused on resource-based conflict such as Land grab in Wadi Salih in Darfur and on natural resources in the Gedarief area of the Red Sea region. There are on water management problems and health hazards related to drinking. This is as well as issues on food insecurity and deterioration of agricultural lands as exemplified by the Toker Delta in the Red Sea region. There were two issues on the two seasonal valleys of Gash and Nyala to show the potentiality for sustainable rural development that could help to reduce the onsets of these regional development problems.

These issues achieve the objective of this book which is to review and discuss some of the regional development problems in the two regions of Darfur and the Red Sea as examples of the central problems facing Sudan. These topics need further writings by authorized researchers to contribute further to suppressing insisting regional development problems of Darfur and Red Sea regions that could contribute to building a future stable and progress in Sudan.

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November 2023

1

**Land Grab by Tribal Groups
in a Fragile Environment,
“Hawakir” of Wadi Salih
Area in Southwestern Darfur**

Land Grab by Tribal Groups in a Fragile Environment, “Hawakir” of Wadi Salih Area in Southwestern Darfur

Pastoralists have interacted with sedentary farmers for millennia. Population growth and increasing commodity production have led to the expansion of agriculture on formerly shared grazing lands, and have increased conflicts between these groups (Fratkin 1997) in Sub-Saharan Africa (Tatlock 2006), West African sub-region; southern Ethiopia, Northern Kenya and Somalia (Mekonnen 2006). Causes of conflict include drought, economic globalization; unsustainable consumption; population growth, and economic warfare (Klare 2001). In Sudan, conflicts over resources are often escalated by high year-to-year variability in rainfall which leads to extreme seasonality and irregular distribution of rainfall over the year (Elagib 2010; Hulme 1990), population increase and the state policies (Ayoub 2006) and over water and grazing rights (Schanche 2007). Hawakir are tribal possession of lands and are lined with animal passages “Masarat” of nomadic tribes. Hawakir were introduced in Darfur by Sultan Musa (1680-1700) of the Fur Sultanate intending to consolidate his power over tribes and migrants to Darfur (Shugair, 1967). This paper looks in some detail into land grab and at the physical and human factors responsible for that in the “Hawakir” of Wadi Salih area in southwestern Darfur.

Wadi Salih area lies at 12^o -14^o N and 22^o – 24^o E, with an area of 22000 km². It is neighbored by Chad from the west, African Central Republic from southwest, Idd el Firsan locality from southeast, and Zalingi locality from east and Genaina locality from the north (Fig.1). Basement complex form the underlying rocks. Surface is plain with some emerging hills such as Jebel Bila, Kartoo, Nebkaia, and Sandoo, and plateaus like Tussy and valleys of Salih, Azoom, Tara Baida, Dabry and Soro. Soils are dominantly sandy with some clayey soils with variable fertility. Rainfall is irregular and erratic with a peak in August and a long term average annual rainfall of 226mm. Natural vegetation is diverse with dominant of *Acacia Nilotica* (Sunut), *Acacia Senegal* (Talih), *Acacia Tortilis* (Seder) and annual and perennial grass species.

Wadi Salih is divided into four administrative units of Dulieg, Garsaiela, Bundus and Um Khier within which Hawakir are distributed. The traditional administrative system is headed by Sharaty for African tribes and by Omda

for Arab Tribes. Tribes live in the study area include Fur, Arabs, Falatah, Masaliet, Dago, Zaghawa, Gimier and Tama and Arab tribes and mobile herders “Marahiel” who come during summer. Farmers settle near valleys, water points and fertile soils and constitute the majority of the sedentary population. People of the study area used to rear livestock, including cattle, sheep, goats, and camels within their neighborhood where their number amounts to 1, 8 million heads, distributed as 850,000 cows; 400,000 camels; 250,000 goats; 137,000 sheep; 70,000 donkeys and 50,000 horses (Pasture Department - Zalingi, 2009).

The research upon which this paper is based was carried out during December 2009 in the Hawakir of Dulieg, north Zami, Fogly, Dagarsa and Duraisa (Fig.1). They were selected by simple random sampling procedure and represent 20% of the total number of “Hawakir”. In each Hakura, a group of 20 farmers and another group of 20 mobile herders “Marahiel” were studied by observation and interviewing through a designated questionnaire. This gives a total of 200 interviewees in whole the study area, 40 interviewees in each Hakura for both farmers and mobile herders. Groups of farmers and “Marahiel” were collected by Heads of their entitled tribes whom were firstly contacted to facilitate interviewing. Because “Hakura” is characterized by irregular streets and houses are built of straw and lack numbering, farmers and “Marahiel” are chosen according to their accessibility during time of interviewing. Interviewing was focused on forms of land grab and responsible factors. Their answers were collected directly to form the base for the fieldwork data of this manuscript. Head of tribes have substantially contributed into the administration of discussion into making language of communication easier. In addition, the fieldwork adopted research type interviewing methodology through general discussions with Head of the tribes, elder people and traditional administrators and focused on forms of land grab and responsible factors as well as current changes in tribal relations and socioeconomic environment of Hawakir. This is as well as collection of relevant office data. Only the percentages were calculated from the questionnaires where indicated to within the results section.

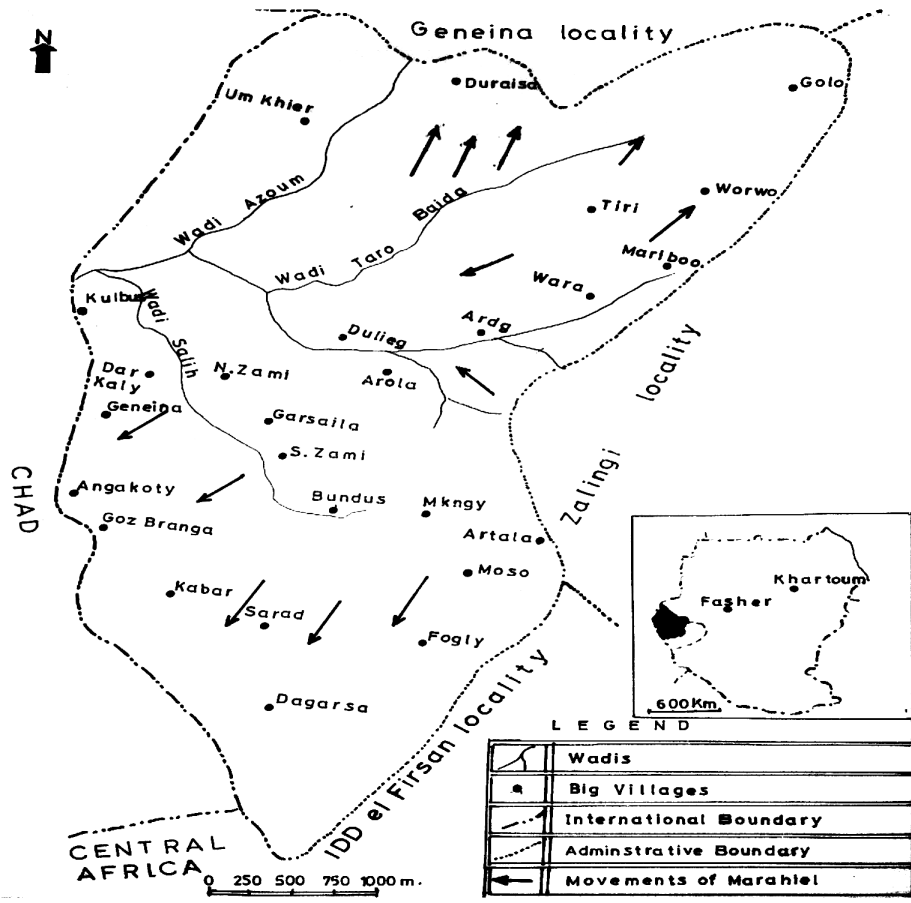


Fig. 1: Wadi Salih area

Forms of Land grab in Wadi Salih

The major crops cultivated are dukhn (bulrush millet: *Pennisetum typhoideum*) and dura (*Sorghum vulgare*), sesame, Arabic gum and groundnut as indicated by 100% of farmers. Dukhn does well on light soils. Its vigorous root system makes it an ideal crop for production on sandy qoz (sandy hill) lands of the study area. Dura does rather better on the patches of more clayey soils, though in practice both crops are grown on sandy soils. Farmers cultivate fields far from animal passages “Masarat” with varying farm size depending on the rainfall amounts as stated by 70% of the farmers. On the other side, Marahiel, and due to harsh climatic conditions, look for pastures and water

where their “Masarat” usually extend 60 km directions-wards as indicated by 80% of mobile herders. Their movements (Fig.1) start at the beginning and end of the rainy season. They move into Dagarsa, Zalingi, Dulaig, Duraisa and Angakoty (Fig.1), concentrating near valleys and mountainous areas.

Farming and grazing have been managed through designated routes for nomadic movements and there are some reserved areas as stated on average, by 82% of both farmers and mobile herders. These are often ignored by farmers who cut off routes and trespasses onto reserved areas in order to deter nomads and to use the reserved areas for agriculture as stated by 67% of the interviewed farmers. They also interfere with water supplies created to assist conflict – free passages of nomads along designated routes. Many Hafirs (dug water reservoirs) were constructed to provide water for livestock but destroyed by farmers to discourage grazers and diverting the stored water for cultivation as claimed by 83% of the farmers. They also destroy some other hafirs constructed for human consumption because nomads were attracted to them and were providing a nuisance to local farmers as confirmed by 55% of the farmers.

Marahiel intrude into field at the beginning and at the end of the rainy season. At the beginning of the rainy season, rains are scanty, grasses are scarce, and farmers are preparing their lands for cultivation. Quite enough is that scarcity in water and pasture drive Marahiel to intrude their animals forcibly into fields even by using guns as happened in Sugy village near Garsaila (Fig.1) between Fur tribe and Arab Marahiel as confirmed by 82% of the mobile herders. It is certain that the true number of incidents is very much higher. Then again, they intrude into fields when they return at the end of the rainy season, when farmers have not completely collected their crops, or have collected their crops and not yet have finished collecting fields’ remnants which are used as animal fodder during dry season or as building material as stated by 67% of the farmers. Marahiel also move into fields inside valleys when rain decreases to graze on crops and fields’ remnants which in confirmed by nearly half the number surveyed of mobile herders (49%).

Leaders of Marahiel and sedentary farmers used to renew landmarks of Masarat when they start disappearing, but nowadays such efforts were neglected by both sides as confirmed by the majority of the two sides, 75% of the farmers and 83% of the mobile herders. Herders will not follow

designated Masarat and similarly farmers expand their fields into Masarat, leaving only narrow passages for animals as stated by 78% of the farmers. In these recurring situations, Marahiel do not take permission to open Masarat and even use guns as happened near Garsaila (Fig.1), when hundreds of acres were added to Masarat as confirmed by 74% of the Marahiel. Confrontations occur when leaders of both sides are not present. To avoid animal looting and killing, Marahiel move into big groups which might also enable them to intrude into fields as stated by 62% of them.

In addition, land grab occur between the tribes live inside the Hawakir on fertile lands, pastures and water sources as stated by 91% of the farmers. The majority of those who have been interviewed during fieldwork could be described as in some way being associated with some of these activities as confirmed by 76% of farmers and 67% of mobile herders. Loss of life, animal and agricultural produce in some localities gives an example to the study area (table1). Total figures give 6413446352 billion Sudanese Pounds (Committee on loss estimation, 1999) which equals 2,137,815 USD, depicting how far land grab and tribal conflicts have seriously damaged local economy of western Darfur including the study area.

Table (1): estimated loss of life, animal wealth and agricultural produce in some localities in western Darfur in 1999.

Human			Animal loss in head					Agricultural produce loss/tons		
locality	dead	injured	lost	camels	sheep	goat	cows	millet	Dura	sesame
Arafa	185	25	55	130	12285	50975	5900	60435	30375	4319
Morny	65	30	55	65	10261	20976	5435	55346	35156	3120
Abas Marra	95	45	12	265	7785	15375	4650	55304	231005	1798
Mustary	25	15	10	20	125	285	929	2343	29527	4363
Habila	69	20	20	25	2285	3725	850	40365	46432	2650
Total	436	117	152	490	32891	91536	15764	555340	52923	25059

Source: Committee on loss Estimations, Darfur states 1999

Factors of land grab

The fieldwork results revealed that environmental fragility; collapse of virtual relationship between farmers and herders; and population increase; dilapidation of traditional administrative system; and lack of basic infrastructure

for community development are the main factors for land grabbing in Wadi Salih area.

Environmental fragility

This factor is stated by 100% of both farmers and mobile herders. Environmental fragility of the study area could be depicted by taking the rainfall records, from 1995 through to 2008, over Nyala town, the nearest longstanding rain gauge which is almost similar to the study area (Table 2). The beginning of the rainy season in late April is characterized by low rainfall amounts and in nine years out of fourteen years, rain did come in April while it has fluctuated between 3 to 14 mm in the remaining five years. Rainfalls in May have recorded 1 mm in some years; 10 to 30 mm in some others years and exceptionally 84.6 mm in 2003, while rains have completely absent in some other years. This gives range value of 83.6 mm (1 – 84.6 mm) and depicts delay of the rainy season, its irregularity and abnormality. In June rains increased, but fluctuating and maldistributed when some years have as high as 157.6 mm rainfall and as low as 0.9 mm rainfall.

Table 2: Monthly rainfalls over Nyala town, 1995-2008

	April	May	June	July	August	September	October
1995	0	2.8	0.9	79.1	145.3	48.6	2
1996	0	3.9	108.7	63.8	70	70.6	29.4
1997	3.4	0	57	193.7	87.5	47	6.7
1998	5.8	24.3	4.4	257.6	107.3	103.4	38.4
1999	0	25.5	8.2	93.9	215.5	112.7	48.2
2000	0	10.7	45.1	127.7	142.7	145.3	34.4
2001	0	10.2	36	111.6	64.5	102.6	0
2002	0	1	17	46.4	95.7	75.5	57.5
2003	3	84.6	109.8	98.2	246.7	76.5	7.3
2004	14	0	20.6	137.1	186.2	39.7	34.8
2005	0	0.1	14.5	272.0	125	70.7	5.1
2006	0	18.1	86.1	132.1	140.7	69.5	3
2007	0	30.6	157.6	97.1	127.1	43.1	3.8
2008	6.8	20.9	25	137.3	249.2	47.8	11.6

Source: Sudan Meteorological Records, 1995-2008.

Rainfall climax is witnessed during July and August. In July rains record as lowest as 46.4 mm and as highest as 272 mm, with range value of 225.6 mm depicting somehow rainfall maldistribution (Fig. 2). Similarly, in August rains record 246.7 mm as the highest record and 64.5 mm as the lowest (Fig.2). From table 2, it can be noticed that rainfall records in some non-abundantly rainy months exceed those records in July and August. This phenomenon noticed in September and even in October. Although a period of 14 years is considered short into detecting behavior of a climatic phenomenon like rainfall, these results might be indicative to environmental fragility exemplified by rainfall fluctuations, delay and shortening of the rainy season.

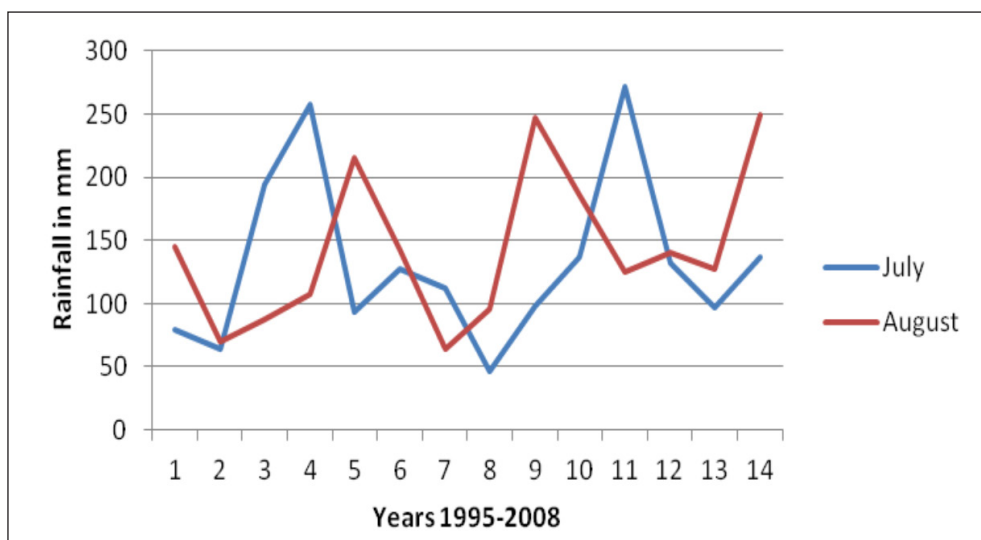


Table 2: Rainfall during July and August over Nyala town, 1995-2008

Rainfall records gave an example to environmental fragility of the study area, but deterioration of natural vegetation is also important as stated, on average, by 69% of farmers and mobile herders. Though the majority of the surveyed population has indicated to successive droughts, declining rainfall and temperature rising as main reasons for deterioration of natural vegetation, 80% of the farmers have also stated that agricultural expansion had cleared up natural vegetation of the study area. Similarly, 73% of mobile herders confirmed heavily grazing as responsible for the disappearance of most of the palatable perennial grasses such as *Aristida* spp., *Panicum turgidum*, *Cymbopogum proximus*, *Memsonia* spp and *Cenchrus bifflorus* and shrubs

and offshoots. Also, natural vegetation was deteriorated it is used for building of annually renewed animal fences and to fill forage gab during summer, as well as logging, of Acacia branches, fruits, leaves. Moreover, the majority of sedentary farmers (81%) stated that use of trees and grasses for building purposes, folk crafts and making of agricultural tools has contributed into natural vegetation deterioration particularly Tamarix tenx 'where the most affected places are located near human settlements.

Collapse of virtual relationship between farmers and herders

Although Hawakir were entitled to a certain tribe, they can be used by other tribes provided a preceding agreement between the sides involved as indicated by 93% of both farmers and mobile herders. Although the tribes of the study area are a hybrid of different tribes, they have succeeded to bring about one homogeneous society on mutual relations between sedentary and mobile tribes, a fact confirmed by 67% of farmers and 58% of mobile herders. The socioeconomic and political environment of Hawakir was consolidated by successive efforts of heads of tribes and enhanced by religious men and People's judiciary organizations which strength tribal political relations as stated by 71% of farmers and 82% of mobile herders. One of these people's organizations is the council of "Agaweed" or mediators and "Fukaha" (religious and wise men) who are responsible for looking into problems of killing, robbery, injuries and organizing joint tribal relations on grazing, water, and agricultural activities where in most cases there are more than forty tribes living together in a Hakura as stated by 69% of farmers. In the past, heads of the tribes usually encourage their people to respect neighborhoods, collective work, exchanging of gifts and gatherings in public festivals to show their folk dances as confirmed by 69% of farmers and 62% of mobile herders. In the past, social cooperation; intermarriage; brotherhood and companionship; and mutual trust enriched social life inside these tribal territories as confirmed by 82%, on average, of farmers and mobile herders.

Economic relations within and between Hawakir have included trading, exchanging of commodities and financial crediting. Trading is practiced into groups at times when any trader can get married with any woman of a certain tribe; he is economically dealing with it. Financial crediting either in the form or animals, had enhanced capital growth between African tribes and

“Marahiel” as indicated by 81% of farmers and 78% of mobile herders. The majority of farmers (75%) and mobile herders (84%) stated that such situation has weakened and no longer exist in some Hawakir.

Generally, tribes used to authorize “Agaweed” to sign peace agreements between confronting peasants and Marahiel, and to pay compensation for life and wealth loss, as sated by 72%, on average, of farmers and mobile herders. These peace efforts were not comprehensive and do not remove bad memories of killing or robbery. Delaying payment for compensations would automatically be met by revenging, or when local folksingers “Hakamma” thoroughly motivate either of the confronting side to take revenge as confirmed by the majority of both farmers (86%) and mobile herders (74%). The fieldwork revealed that the well-established socioeconomic bounds between farmers and mobile herders has almost weakened, a factor perceived by both sides as triggering land grab in the study area as stated by 88% of farmers and even more by mobile herders (94%).

Dilapidation of traditional administrative system

Although Hawakir were basically introduced as common resource for tribes, but in some situations Hawakir were privately owned by some traditional administrations and landlords and hereunto there is private or “Gah” Hawakir with areas of more than 150000 feddans. The majority of Hawakir were not officially registered, or being officially registered conditioned that Sharaty or Omda signs first as stated by 89% of farmers. They distribute land in order to get “Oshour” or tenth of harvest. When a family owns a field inside a Hakura, it also pays Oshour to the entitled local administration as well as to its representative to the Hakura office who eventually receives 1/3 of the harvest as confirmed by 91% of farmers. Local communities regard these “Oshour” as depriving their income and as a form of feudalism as stated by 69% of farmer.

Due to communist thought of the military government of May 1969, traditional administration has been concealed by the decree of Local Governance in 1970 which overruled the authority of such administrations over local communities. Land became the State property and the new administrative system has brought some officers who do not belong to the local people or to the study area as indicated by 71% of farmers and 69% of mobile herders.

In addition, returnees to the study area, who have migrated during droughts, disobey their entitled local administrations; and similarly, criminals were not punished as stated by 59%, on average, of farmers and mobile herders. This have encouraged armed looting of villages and animals as stated by 87% of farmers and 94% of mobile herders. Such armed groups have occupied, for instance, valleys of Shagy and Kalash which lay between Zalingi and Wadi Salih area twice in 1989 and 2007 and closed roads leading to villages as confirmed, on average, by 74% of farmers and mobile herders.

Lack of infrastructure

Although Wadi Salih area is rich with natural resources and human manpower, its population considers it the most underdeveloped area in Darfur as stated by 90% of both surveyed populations. Here, general community services are rare. Water stations are few and subject to pressure during the summer season due to huge numbers of human and animals as indicated by 89% of farmers and 96% of mobile herders. Moreover, electricity service is absent, and there is only one hospital with one general doctor; and few almost closed up rural dispensaries, but had been replaced by some non-governmental organizations which offer free medical services as stated by 95% of farmers and 88% of mobile herders. Still yet, average of students per class is 80-100 students, with only six basic schools distributed within the four administrative divisions of the area, and two secondary schools for girls and boys. Schools are lacking infrastructure and adequate staff while some are closed up (Education Office, Dulieg 2009). Accordingly, higher levels of illiteracy and educational loss, in the view point of some farmers (84%), and mobile herders (69%) and heads of tribes (83%) were responsible for land grab and tribal conflicts. Also, Wadi Salih area lacks agro-animal based development projects that enhance community development as well as roads that could link the study area with other parts of Sudan. So far, these situations have been exacerbated by population increase from 272573 in 1990 to 587896 in 2000 with estimated annual increase by 3.1% according to Wadi Salih Hospital in 2009 as (40%),

Discussion

Colonial socio-economic policies left the illiterate majority of Africans as either pastoralists seeking for pastures or traditional agriculturalists producing for self-subsistence. Post-Independence Africa was therefore challenged

with very violent resource-based conflicts and tribalism. In Darfur, which has been governed by Fur Sultanate, Ottoman Empire and the British, live more than one hundred African and Arab tribes. Land grab and tribal conflicts are persistent over 1970's between Taáisha and Salamat tribes, in 1990's between Ma'alia and Ruziegat tribes and in 1996 between Masaliet and Fur tribes against Arab Tribes, for examples. Wadi Salih area is not exceptional to other parts of Darfur where the conflict was over water and grazing rights (Schanche 2007). The areas of the Fur, Birgid, Berti and Daju tribes then became targets for waves of displaced groups from Northern Darfur, especially the Zaghawa and various camel pastoralists whose traditional grazing lands had suffered (Ayoub 2006).

There is clearly a close relationship between climate and land grab in the study area. This part of Sudan has suffered from considerable rainfall fluctuations during the 20th century. In general terms, the rainfall was considerably higher during the 1950s and early 1960s and in 1977 Wadi Salih area has been classified by the United Nations under "very high risk" of desertification (United Nations 1977). Changing climatic conditions in the Sahelian zone had seriously caused many dramatic changes in the traditional subsistence societies living there. The imperative inflicting ecological changes disturbed the rhythms of grazing, cultivation, and migration, where tribal conflicts are expressions of unstable societies living in Hawakir. Ecological fragility is associated with worldwide climatic change. For the Sahel zone June rains (early season) are generally good in El Nino years, whereas July-September rains (main season) are reduced (Zeng, 2003). Averaged annual rainfall decreased markedly since early sixties in Sudan where it varies from almost nil in the north to about 1500 mm at the extreme southwest of the country (El Gamri et al., 2009). Yet, drought is a part of the climate system and has slow onset which is unavoidable (Mutua 2004), where an unanticipated severe drought will be a feature of the climate in the future as it has been in the past (NSF, 2003). However, recent studies on global warming indicated to higher rates of heating in Africa, where the surface area of Lake Chad which is located at same latitude of the study area, has decreased from 25,000 km² in 1963 to 1,350 km² today. Modeling studies indicate the severe reduction results from a combination of reduced rainfall and increased demand for water for agricultural irrigation and other human needs. The other side of ecological fragility is the deterioration of

natural vegetation with its repercussions on loss of pastures and agricultural lands are well documented in Sahelian zone of the Sudan. It is not, however, merely the total biomass that gets over-exploited by grazing and browsing animals, it is the selective exploitation by stock of particular palatable species that is really important. As a result, vegetation may still appear quite dense after heavy grazing, whereas in fact selective grazing has eaten out many of the palatable species and reduced the carrying capacity dramatically (Davies, 1987).

The resident population of the study area tends to increase their cultivation area since coefficient of variation of the annual rainfall is about 30% the area cultivated and the productivity varies widely from one year to another (MOIWR, 1999). To do that they clear wide areas to grow crops and so compete with livestock for both land and water. Although the Agricultural Conference held in 1973 recommended the stopping of rainfed agriculture in areas with 300 mm and less to stop environmental degradation, people still cultivating this area (Ibrahim and Al/Ghani 1983). The ignorance of suitable climatic boundaries for agriculture was one imperative reason for desertification (Iskander,1989). These ecological and environmental problems in sub-Saharan Africa have affected the food system of the communities living there. Half the population in sub-Saharan Africa lives below the poverty line, with both numbers and percentage on the increase (Alredaisy & Davies, 2001). The drought of 1984 resulted in crop failure and internal migration to urban centers, and the weakening of the socioeconomic capabilities of the nomadic tribes in Sudan (Osman et al., 2002), such as those Arab Marahiel in the study area.

Ecological fragility could be thought of to be related to retarding National efforts for socioeconomic development of the study area. Land grab reflects resource mismanagement in arid Sudan. For centuries, resources were utilized by simple and primitive means. No innovation or modernization of production means was introduced. Traditional farmers cultivate their lands using same agricultural tools, labor force and marketing. Animal herders depend on natural pastures moving following same passages inherited for centuries. They depend solely on nature giving. No strategies to settle and promote this sector are seen into Sudanese development planning. Problems of international boundaries demarcated by colonial powers have introduced

concepts of land partitions and land fidelity among these traditional societies. The nomads in particular do not have the idea of a boundary and they own what they see in front of them. Generally, some development programs of the Sudan have suggested some development projects in Darfur. During Condominium (1898-1956) development policies concentrated in the period 1899-1919 on transport and expenditure on agriculture was relatively low. From 1919-1939 expenditure on agriculture increased to 58.6% (Beshai, 1976:14) while in the development program of 1946-1951 no development programs were designated for Darfur. The development program of 1951-1956 witnessed the extension of railways to reach Nyala in southwestern Darfur. National Governments (1956- on) also tried to follow on developing the Sudan and the development program of 1957-1961 looked for improvement of the rainfed sector apart from private mechanized agriculture. In addition, the ten- year plan of 1961/62-1970/71 had proposed the development of Jebel Mara and the production of short – stapled cotton in the rainfed sector and the five-year plan of 1970/71-1974/75 proposed settlements of the nomads. The six-year plan of 1977/8-1982/3 also did not recommend any development programs for Darfur so that the project of Desertification and Drought Relief for digging boreholes was also not implemented. The prominent development project during the last years is the implementation of “Western Ingaz Road” to link all Darfur together and with all other parts of Sudan. It links between el Fasher- Kass- Nyala and Zalingi to reach ultimately to el Genaina town and before that it is linked with Obied, Kosti and then central Sudan.

Rationalizing for retarding socioeconomic development in the study area, and in other similar parts in Sudan, is that Condominium and post-independence governments believed that the future of Sudan economy lies in commercial agriculture and has failed to provide any development strategy for the traditional peasant sector which holds the majority of Sudan’s population (World Report, 2001). Neglect of rainfed sector by successive Governments is partly due to that large investment sums which would be necessary to provide an adequate infrastructure of roads and marketing in such areas, without any attempts to develop peasant rainland farming effectively cannot succeed (Alredaisy and Davies, 2001). Rural water provision has been expanded dramatically without sufficient thought, so that considerable area of western Sudan has been degraded by over-cultivation

and over grazing since 1960s and became more severe problem during the 1970s and 1980s (Awad et al., 1985). The truth of this has been made plain by recent work in West Africa (Cour and Snrech, 1998) and by Lange (1985) who indicated that large numbers of animals and few water points leads to a heavy intensity of movement with 'ponching' of the ground, and to heavy grazing around them.

When tribal lands or Hawakir were created by the Sultans, they have satisfied aspirations for their societies. They were validated by these tribal societies so far, because it is part of their social norms that wise men are worthy to govern their societies and possess huge lands. British rule in Sudan enhanced traditional administration intending to consolidate their power over tribes and similarly did the following government after independence in 1956. Though abandoned in 1970 in most of Sudan, it continued in Darfur due to its tribal structure and remoteness from central Government. Land grab might indicate to changing local attitudes towards traditional administration and land ownership and to changing social attitudes. These traditional communities might have entered a new social era due to globalization and political relationship between center and periphery in Sudan as exemplified by raised issues of equality by rebelling military peripheral groups which have led to the separation of South Sudan and the emergence of conflict in Darfur.

Land grab might depict the impact of nomads into uprooting sedentary communities as the nomads of the North African desert, who have come from within and without Darfur, are committing devastating blows to these tribal territories in Darfur. Semi arid territories south of the Sahara are going to be added to the nomads' desert homeland. Nomads used strongly to destroy civilization as Bin Chaldean indicated in his "Introduction" since they are misconnected with a boundary or a State. By that way, the changing boundaries of tribal areas might form the new ethnographic map of Darfur. Ethno-tribal conflict might be an imperative cause for pushing Arab tribes outside the area or vice versa, might disconnect their geographic continuity with other Arab tribes in Chad and Mali through impounding continuous ethnic barrier of African tribes connected with Central, western and southern Africa.

Incompetence of Hawakir into security provisioning to their inhabitants led to tribal weakening of alliances and further disturbed by blowing storms of new political alliances taking over the traditional administrations inside these tribal

territories. From the Hawakir emerged the military rebellious movements in Darfur raising issues of equality and justice and viewing their societies as underdeveloped and lacking basic services for community development.

CONCLUSIONS

1. Land grab in Wadi Salih gave an example to Darfur.
2. Tribal conflicts took the form of intrusion into farms by animal herders while farmers and cut off animal passages and trespass onto reserved areas and destroy of hafirs.
3. Land grab is due to environmental degradation, collapse of the virtual relationship between farmers and herders, dilapidation of traditional administrative systems; population increase, government neglect of the traditional subsistence sector; lack of basic infrastructure for community development, and migration from Chad and absence of proper development policies for arid Sudan.

The Fur tribe Omoda in Dulieg (Fig.1), stated that “ Hawakir had enforced Tribal fidelity and strengthened the concept of tribal territory and some tribes wish to increase their area of Hawakir to gain political power. Every tribe declares absolute ownership on land and considers its land “holy Dar” that one should martyrs for it”.

Many peace conferences were held to alleviate tribal conflicts and land grabbing in Darfur including El Fasher Conference on peace between Fur and Arab tribes in 1989, Kutum Conference in 1994, Genaina Conference in 1996, Duaain Conference in 1997, and Nyala Conference in 2007 between Turgoum. It is of course, difficult to completely eradicate these tribal territories in Darfur but, policies of alleviation of tribalism in these agronomic base societies and suitable development projects could help in promoting them to cope with changing conditions.

Research in Sudan has shown clearly that to be successful, any innovation in the agricultural base societies must fulfill four main criteria. It must fit into the existing physical environment conditions; be economically viable; be acceptable in terms of the existing socio-cultural constrains; and take into account the available administrative and managerial manpower (Davies

1987). Based on that experience, promotion of Hawakir in Wadi Salih has been recommended in figure (3) as based on local people suggestions during the fieldwork. This include introduction of suitable means for water and pasture resources management; new educational curricula for social equality and tribal alleviation in schools; new administrative system instead of the decaying “traditional administration”; introduction of co-operative agricultural units; and diversification of activities since many is employed in marketing service enterprises as many of them already have more than one occupation, nevertheless, both occupations so often depend upon local natural resources; alternating fuelwood by solar energy; viable interregional commercial relations with other regions of Sudan and activating economic relations in Sudan - Chad – Central Africa triangle. Africa has to demolish tribalism to settle socially and politically. The formation of economic agglomerations, like the COMESSA and the United African Union, are good steps towards demolishing tribalism in Africa. But, linking African societies by reorganizing border lines is essential.

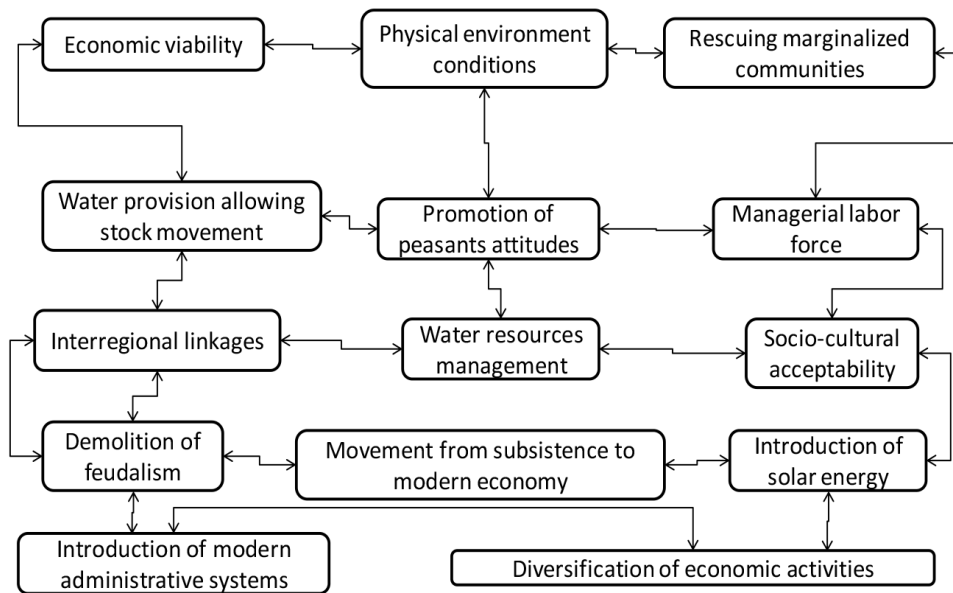


Fig.3: A suggested strategy for the of Hawakir in Wadi Salih area, southwestern Darefur, Sudan

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2

Water Management Problems in Eastern Darfur

Water Management Problems in Eastern Darfur

Sudan extends between marginal desert lands in the north to the rich savannah in the south. Although Sudan is rich with water resources, but the desert marginal lands face water scarcity due to their vulnerability to climate change; desertification; and anthropogenic effects. These desert marginal lands are under threat from sand creep and desert encroachment and have been affected by changing characteristics of the rainy season since early sixties (Zeng, 2003) and global warming, rapid increase of human and animal population as manifested by deterioration of natural vegetation (Davies, 1987). In these marginal lands, water insecure groups of the Sudan are found, who are usually poor, self-provisioning producers (Green 1989; World Bank 1990; Knerr 1998) and are pushed by land hunger into ever more marginal lands in term of weather, soil and ecological fragility (Alredaisy and Davies, 2000).

The climate in Darfur varies from less than 50 mm in the northern part of the region to more than 1000 mm in the higher altitude savannah regions of south and west Darfur. Annual coefficient of variation of rainfall is more than 40% in the northern part compared to 30% in central Darfur, i.e. highly seasonal and highly variable. Also, annual rainfall shows decreasing trends and a marked shift in rainfall isohyets towards the south (Yousra and Magdoline, 2009). North Darfur rainfall records show increased frequency of droughts over the past 40years. Sixteen out of 20 driest years on record in north Darfur have occurred since 1972. It appears from the above figures that the climate in Darfur is influenced by global climate change. There is an extended Sahel drought of the last few decades where rainfall trends are decreasing from 1898through to 2002(Hutchinson and Hermann, 2008). There is a shift of the desert boundary between 1958 and 1975 (Lamprey, 1988), and there is a decreasing trend in the annual rainfall of Genaina town in west Darfur for the period 1943-2006 (Abdo and Salih, 2011).

Water is a primary resource from whose scarcity much other strife emanates is confirmed by the fact that, the Darfur conflict is strongly linked with lack of adequate water supply to meet the immediate demand of population. It has been estimated that current water supply in Darfur Region represents only about 14% of the required domestic and livestock demand (Abdo and Salih, 2011). Available records on conflict in Darfur indicate that out of 49 recorded

conflicts took place during the past six decades; more than 75% of them were triggered due to high competition over water and pasture during low rainfall seasons (UNDP, 2007; UNEP, 2009). In Wadi Salih area in southwest Darfur, 83% of the farmers interviewed indicated that they interfere with water supplies created to assist conflict – free passages of nomads along designated routes, where many water reservoirs (Hafirs) were constructed to provide water for livestock but destroyed by them to discourage grazers and diverting the stored water for cultivation (Alredaisy,2012).

There are many complications to manage water in Sudan because of natural scarcity, funding and human resources, social disruptions including war, famine, drought; and future uncertainty due to climate change; and cultural complexes. Inadequate funding is essential element into mismanagement of water resources in Sudan as it was connected with accelerating rates of inflation and high expenditure on civil wars in south and western Sudan, as well as corruption in the administrative system of the country. Social disruptions are effective as they divert efforts to spend on non-productive revenue. Climate change threatens social fabric of local communities and makes them vulnerable to future uncertainty and might cause cultural complexes. The past experience of rural water provision end to a failure as water points have been expanded dramatically without sufficient thought, so that considerable areas of western Sudan have been degraded by over cultivation and overgrazing since the 1960s, with the problem becoming much more severe during the 1970s and 1980s. Still there are insisting current needs for water in Darfur. According to Abdo and Salih (2011), current renewable water supply in Darfur represents only about 14% of the required demand. This demonstrates the very critical water supply in Darfur. The current demand represents less than 7% of the renewable water resources. Therefore, water availability is not a problem in Darfur but it needs an integrated water management plan that ensures the provision of sustainable water supply to meet livelihood needs of the people of Darfur.

Background

This paper objects to produce an integrated plan to alleviate water management problems and promote water use in the study area. This plan was integrated with issues of governance, environmental conditions, and social contexts to offer a powerful “plan” for guiding future water management

in a more sustainable and effective manner. This plan consists of eight axes, five responsible bodies for realization of the plan; and a time schedule of three phases for its implementation (see Figure 9). The justification for the important general considerations for an integrated management framework in this region comes from the current insisting water management problems and that, although water resources are available and capable to meet current demand, managerial problems hinder its use effectively, and also water resources sector is not accommodating with current and future challenges facing this sector such as climate change, increasing population due to migration caused by internal conflicts ignited by water stresses. These considerations will then be refined by the results of our analysis and interviews to define “Axes” of our current plan

Defining of local hydrological terminology for the study area is shown by Figure 1. Hafirs are dug water reservoirs usually duo by government authority for either human or animal consumption. In the study area, the majority were dug during early 1970s as part of a national program for combat thirst in western Sudan. Rahads are depressions or natural hollows receive flowing rainy water might be from some remote areas and usually used by human and animals. Tebaldi “Adamsoniadigitata” are huge trees belong to Acacia family; where their stems are hollowed to conserve water during dry season. Gardud is a covering of sands (qoz) interrupted with clays. Gardud usually found in somehow very low level areas where rainwater can accumulate during rainy season and dries quickly forming cracked surface.

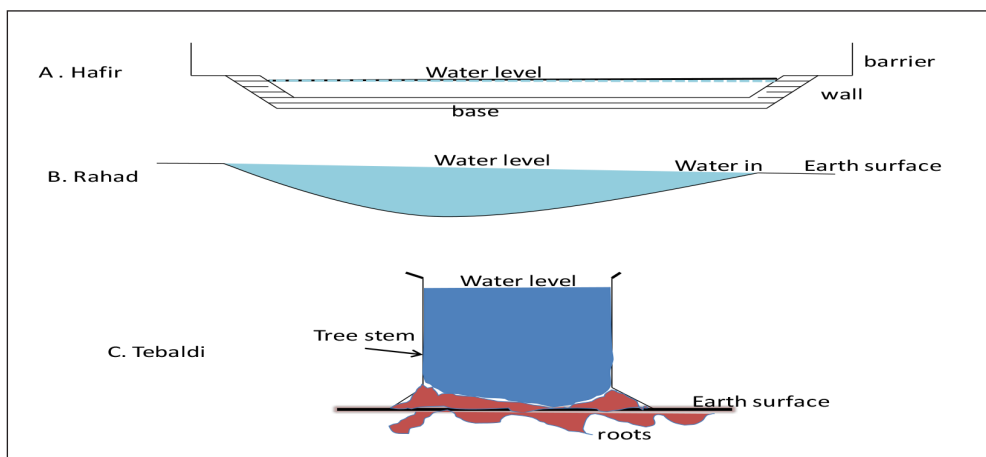


Figure 1: local types of keeping water and their terminology in east Darfur

he hydrological cycle in the study area in terms of these local hydrological components could be conceptualized in Figure 2. Rainfall superficially flows into Wadis (valleys) which have base soils of clay and sand and fills up hafirs and Rahads and Tebaldi “Adamsoniadigitata” and/or discharge aquifers which feed water stations and surface wells. The area receives some water from seasonal valley coming from neighboring areas. These water bodies lose some of their stored water through evaporation and penetration to subsoil. It is expected that, open surface bodies of Hafirs and Rahad to have higher evaporation rates compared to Valleys and Tebeldi, particularly during dry season, while they receive higher water input during the rainy season.

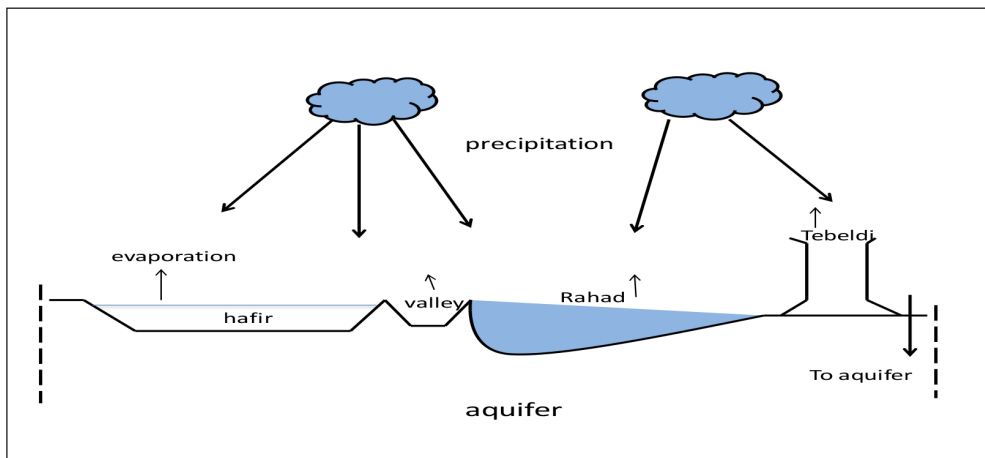


Figure 2: A Conceptual Hydrological Cycle in East Darfur

Study Site

The study area constitutes the eastern part of North Darfur State, and administratively divided into Umm Kedada, Toaisha, and Laitgarelnabi localities at latitude 13° 40' N (Fig.3). It has an estimated area of 4000 km². The majority of the population is settled into small villages near water supply points and where soils are suitable for cultivation. They are mainly farmers cultivating dukhn (bulrush millet: *Pennisetum typhoideum*) which is an ideal crop for production on sandy qoz lands (Bacon, 1954); and dura (*Sorghum vulgare*), sesame, Arabic gum and groundnut, and people also rear cattle, sheep, goats, and camels. The general physical characteristics are essentially those of underlying rocks, which belong to the Basement complex. Over this lies a covering of sands (qoz) interrupted with gardud with the former

becoming more prominent. Umm Kedada basin is an eastward extension of Wadi Hoar basin, and composed of Nubian sandstone formations. South of Umm Kedada basin lays Toaisha and Laitgarelnabi on the northwest part of Bagara Basin which is composed of Nubian sandstone deposits of sand and gravel. As a result the study area has to rely upon shallow wells for its water supply; though there are also a number of hafirs where rainwater can collect and some valleys with base soils of clay and sand. Rainfall is erratic and irregular, particularly in the north part, and higher in southern parts, with a long-term annual average rainfall in the order of 300 mm falling in three summer months of the year. Due to these harsh environmental conditions, big size of the area, and natural increase of human and animal population, there are many managerial problems concerning public services, particularly the water sector. Problems of funding, maintenance, technical staff and administration are serious in this sector. High demand for water and its shortage during dry season exacerbate managerial problems to local authority.

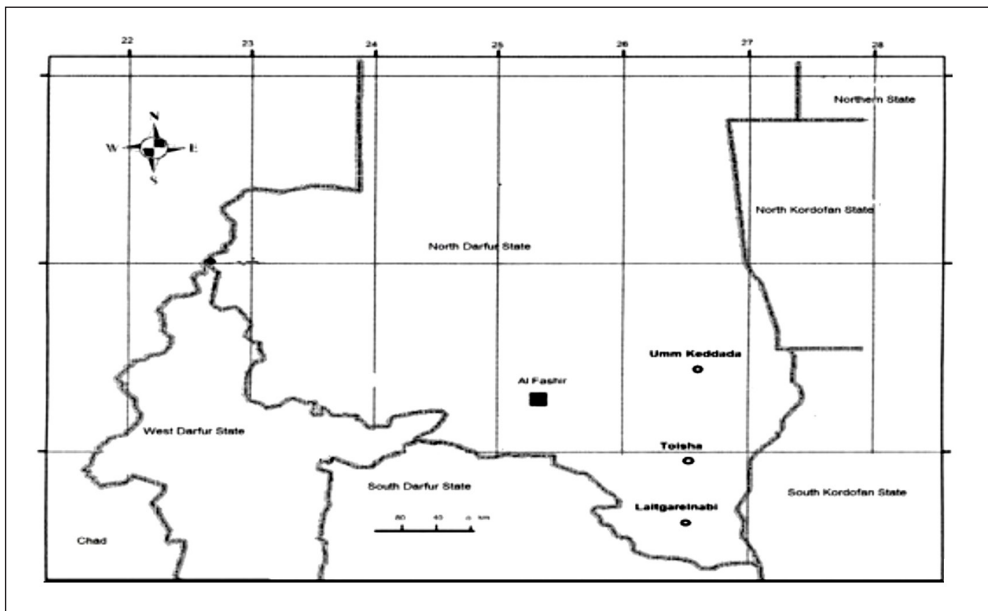


Fig.3: Location of the study area

Source: After Department of Survey, Al Fashir town, 2009

Data Sources:

Data sources included interviews and official relevant office data provided by governmental and nongovernmental sources. These data were used to discuss types and nature of water sources, levels of production and consumption and problems of water management during 2009. This is in addition to direct field observations. Interviews took place with water technical staff; resident water staff in water stations, as well as heads of water authority in each of the three localities under study. Interviews also took place with representatives of some NGO's working in these localities including British Childhood Care Organization, OXFAM, Sudanese Red Crescent, and Intensive Labor non-governmental organizations.

Hydrological data sources included rainfall, water stations production, consumption, and climate change and projections. Rainfall data over the three localities (Umm Kedada, Laitgarelnabi, and Toisha) was obtained from local meteorological stations. For every locality relevant data for water stations was collected from annual records files in Rural Water Administration. Data on the estimated water consumption for human and animal population was also collected from the same source. Data on the chemical properties of drinking water in Umm Kedada area was provided by the Administration for Non Nile Waters in El Fashir, while for Laitgarelnabi such data was provided by the Administration of Rural Water Station in Umm Kedada. Such data was not available for Toaisha.

Characteristics of water salinity in Umm Kedada basin were obtained from Kander's study of resources and water sources in Darfur state (Kander, 1992). Data on depth of static water level, total storage, recharge and abstraction of Baggara, Umm Keddada, and Sag El Naam basins was obtained from Darfur Joint Assessment Mission Report which was done by United Nations Development Program (UNDP, 2007). Climate change data was collected from relevant literature in Sahelian Sudan and some other studies done in the study area. The study by Abdo and Salih (2011) provided data on projections of water demand by human and animal populations till 2020. The determination of water budget for each locality is based only on water production data provided by water stations due to absence of relevant data for other water sources. Population data was obtained from Statistics Offices in each locality, and similarly animal data was obtained from Veterinary Department in each locality.

Statistical Methods:

The available statistics were treated at the local geographic location and for whole the study area following its general administrative map. Means of annual rainfalls were calculated. The midpoint method of finding the mean of water production by water stations was calculated for whole the study area and for each of the three localities separately by using the formula:

$\bar{X} = \frac{\sum \text{Mpt. } f}{\sum f}$, where **Mpt** is the midpoint for each class interval, f is the frequency of each class interval

The grouped frequency distribution method was used to calculate the standard deviation for water production by stations for the whole study area by using the formula: $\sigma = C \sqrt{\frac{\sum fd^2}{N} - \left[\frac{\sum fd}{N}\right]^2}$, where $\sigma = \text{SD}$, $C = \text{class size}$, $f = \text{frequency of each class size}$, $d = \text{deviation from arbitrary point of origin which starts with the class interval with the highest frequency}$, $N = \text{number of cases in the distribution}$, $fd = \text{sum of product of frequency and deviation from the arbitrary point of origin for each class interval}$, $fd^2 = \text{sum of product of } fd \text{ and deviation from the arbitrary point of origin for each interval}$. The Chi-square technique was used to determine type of geographic distribution of water stations, which were already grouped into classes according to daily water production per water station. The formula used is:

$\chi^2 = \frac{(A-B)^2}{B}$, where: χ^2 is the calculated Chi-Square value, A is the observed distribution, B is the expected distribution.

The equation used for the calculation of the SD is: Amounts of water in British Gallon, where 1 gallon equals 4.5 liters, were converted into cubic meters and liters. One cubic meter equals 1000 liters or 222.2 British Gallon. The per capita per day and annual consumption of water were expressed into liters and calculated as average consumption.

Natural water sources and distribution

Water sources in the study area include rainfall, which superficially flows into Wadis (valleys) and fills up hafirs (dug water reservoirs), Rahads (depressions or natural hollows) and Tebaldi "Adamsoniadigitata" and/or discharge aquifers, in addition to water stations and surface wells. Rainfall records indicate a long-term average annual rainfall of 154 mm over Umm Kedada,

434 mm over Laitgarelnabi, and 281 mm over Toaisha (Figure 4). The wettest year during the period was 2007 for Umm Kedada, 2009 for Toaisha, and 2008 for Laitgarelnabi. The driest years were 72 mm for Umm Kedada, 155 mm for Toaisha, and 243 mm for Laitgarelnabi. Rainfall decreases southwards. Records of rainfall over Laitgarelnabi are very close to those over Ed Duiem, while Umm Kedada fits Sahelian Sudan rainfall records. Discrepancies of rainfall distribution are less than Laitgarelnabi, where the ups and downs of the curve are less sharp. This might indicate that a rainfall rhythm in the north part of the study area is symmetric, and asymmetric in the southern or might also indicate also to that the southern parts are entering a phase of sharp fluctuation of rainfall due to climate change. Toaisha's graph depicts a middle location between Umm Kaddada in the north and Laitgarelnabi in the south, as if it is a transitional zone between both.

Valleys are rare; usually provide little water during the rainy season, though some might flow whole the year such as Umqozain valley according to the characteristics of the rainy season. Valley base soil is usually a mixture of sand and clay, have high permeability and porosity. These characteristics enable people to dig for subsoil water which is locally called "gamam" and supply water during the dry season. The total average Wadi flow for north Darfur (including the study area) has been estimated as 100 MCM/y concentrating during the rainy season from June to October (Abdo and Salih, 2011).

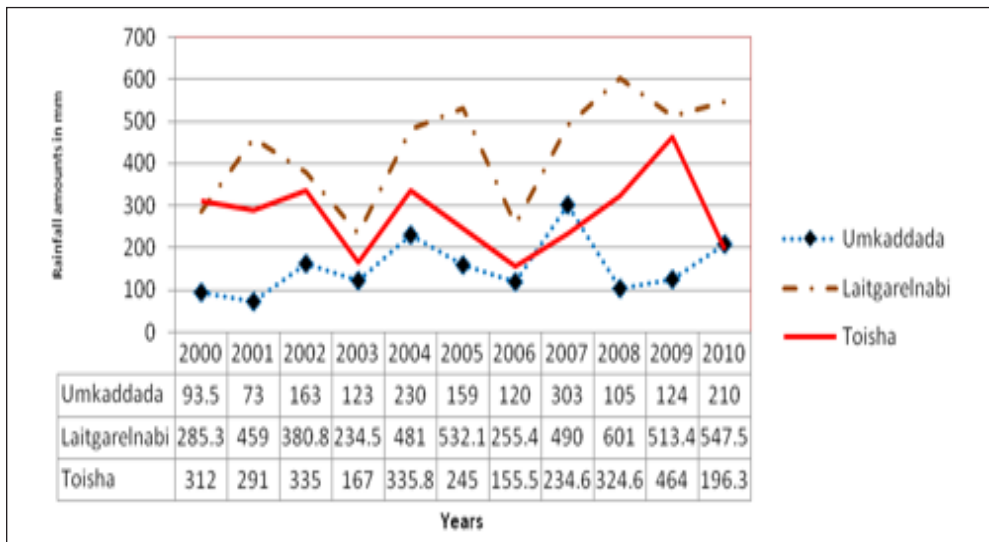


Fig.4: Rainfall over Umkaddada, Laitgarelnabi and Toish: 20000-2010

Hafirs can store water for a considerable period of time following the end of the rainy season. In some villages, Some Hafirs were excavated close to valley courses with soil horizons of 2–8 m thickness. Umm Kedada, however, is a predominantly sandy region, devoid of mountains and hills that would otherwise increase water drainage into hafirs. Consequently, hafirs depend solely on rainfall for recharge, and being thus shallow, and do not last long due to evaporation which depletes, particularly when these hafirs have been overpopulated by human and animal population, have lost natural vegetation that protect their embankments and subjected to excess sand accumulation due to sand encroachment. Rahads are accessible to human and animals; keep water for dry period and might stay longer in some villages. Rahads are common in Umm Kedada locality; necessarily differ in size due to rainfall amounts, evaporation rates, wind speed and nature of base soil. They were subject to the main threats of the hafirs. Hafirs are more found in the eastern parts of Umm Kedada, completely absent in Toaisha and there is only one in Laitgarelnabi which might due to low rainfall and drought which drives people in the northern parts of the study area to harvest water using hafirs. In addition, rainwater was harvested using Tebaldi “Adamsoniadigitata” hollowed trucks, barrels, and tanks. This traditional technique is old and used widely and was more influential when rainfall was abundant and the natural vegetation was denser. However, deterioration of natural vegetation and disappearance of “Adamsoniadigitata” have reduced the efficacy of this method for water conservation.

Baggara basin has a n area of 60,000 km², the depth of static water level is 20-100 m with total storage of 300,000 MCM/y, recharge of 250 MCM/y and abstraction of 7 MCM/y. Umm Keddada basin which starts from north of Bahr el Arab water divide and connects westwards with Saq el Nia’am Basin and southwards with Bagara Basin, has an area of 5500 km², 20-50 m depth of static water level, total storage of 30,000 MCM/y, and recharge of 21 MCM/y, and abstraction of 2 MCM/y. Sag El Naam basin has an area of 2250 km², 60-95 m depth to static water level, total storage of 100,000 MCM/y, recharge of 20 MCM/y, and 0.5 MCM/y abstraction (UNDP, 2007). Artesian wells in Umm Keddada basin range between 20 to 50 m depth, while in Toaisha, artesian wells range between 13-24 m in depth and similarly Laitgarelnabi.

The study areas suffer long dry season and water shortage, some people have invested into privately owned hand pumps which were highly productive in Laitgarelnabi, compared to Umm Kedada although it possess more, also related to aquifers characteristics. Tebaldi “Adamsoniadigitata”, as a water harvest system, spreads more in Toaisha, less in Umm Kedada and absent in Laitgarelnabi. This might be related to more reliable rainfall amounts in Laitgarelnabi relative to Toaisha and Umm Kedada as well as dense vegetation.

The total number of water stations in the study area is 66, distributed as 22 in Umm Kedada, 16 in Toaisha and 26 in Laitgarelnabi. The Chi-Square statistics for geographic distribution of these water stations give value of 2.5 for Umm Kedada, and 0.6 for Toaisha, and 13.1 for Laitgarelnabi. These figures depict that they are uniformly distributed in Toaisha, randomly in Umm Kedada and clustered in Laitgarelnabi. This geographic distribution might indicate that, although Laitgarelnabi has equal area to Toaisha and small area relative to Umm Kedada, it exceeds both areas. This might due to that artesian water could be found at range of 13-24 m in Bagara Basin compared to 20 to 50 m in Umm Kedada Basin. However, 25.6 % of total water stations are not operating in the study area, distributed as 46% in Umm Kedada, 12.5 % in Toaisha, and 4% in Laitgarelnabi. This due to many problems, amongst which are managerial problems. This situation is also applicable to surface wells, where 52% of them are found in Umm Kedada, 54% in Toaisha and 29% in Laitgarelnabi. Generally, the percent of not operating wells exceeds that for water stations, and therefore, it is expected to contribute less in the total water budget of the study area. The general geographic distribution of not operating water stations and wells decrease southwards, where Umm Kedada suffers most although possesses more water stations and wells. This reflects geological, climatic and managerial problems.

The main source of outside support comes from British Childhood, OXFAM, and Sudanese Red Crescent, and Intensive Labor non-governmental organizations. They have collectively, with more emphasis to British Childhood and OXFAM, rehabilitated 258 water sources including 51 water station, 49 hafirs, 79 well, 52 hand pump and 27 Rahads in whole the study area.

Water production

Various water sources, excluding rainfall, contribute into the total annual water budget of the study area which is estimated at 20,854,253 m³ annually. They are distributed as 514,966 m³ for water stations; 277,483 m³ for surface wells; 55,496 m³ for hand pumps; and 27,748 m³ for hafirs; and 54,000 m³ for British Childhood Care organization contributes; and 19,978,560 m³ other nongovernmental organizations. Seasonal distribution of water production by water stations in the study area depicts that, during summer, Umm Kedada with 202,500 m³ exceeds Toaisha and Laitgarelnabi, which both have almost equal figures, with 26,822 m³ for Toaisha, and for 26,795 m³ for Laitgarelnabi (table 1). During winter, still Umm Kedada ranks first (101,250 m³), while Toaisha and Laitgarelnabi are significantly different, with 40,090 m³ for Toaisha and 13,397 m³ for Laitgarelnabi (table 1). This situation is reversed during the rainy season (table 1), when Laitgarelnabi with 53,590 m³, has fivefold the amount of water production in Toaisha which is 10,022 m³, and even exceeds Umm Kedada (40,500 m³).

Generally, the study area suffers water scarcity at the beginning of the rainy season. More rainfall in the southern parts of the study area ranks Laitgarelnabi first during the rainy season while for the other two seasons; Umm Kedada ranks first, although it possesses less water stations, more not operating ones, compared to Laitgarelnabi. The reason for that might be attributed to efficient management of water stations or to some other reasons that were not investigated during the time of fieldwork.

Table 1: Total water production of water stations by season by locality in 2010 (m3)

locality	Summer	Winter	Rainy season	Total
Umm Kedada	202,500	101,250	40,500	344,250
Toaisha	26,822	40,090	10,022	76,934
Laitgarelnabi	26,795	13,397	53,590	93,782
Total	256,117	154,737	104,112	514,966

Source: Rural Waters Corporation, 2009, Umm Kedada

The distribution of hourly water production by water station by geographic area is shown by Figures 5, and 6, and 7. In Umm Kedada (Fig.4), the

highest production per water station was 20,250 liter which equals 20.25 m³, and was recorded in three locations representing 13.5% of the total number of water stations in Umm Kedada (Fig. 5). On the other hand, the lowest production per water station was 4500 liter which equals 4.5 m³, and was recorded in five locations representing 23% of the total number of water station there. These statistics give average water production of 3.2 m³ / h (3,168 liter / h) and the standard deviation of 7.5 m³ / h (7,461 liter / h) (table 2), and range value of 15,750 liter or 15.75 m³. The difference between the average and the standard deviation is big which was confirmed by the range value, indicating discrepancies in water stations production in Umm Kedada.

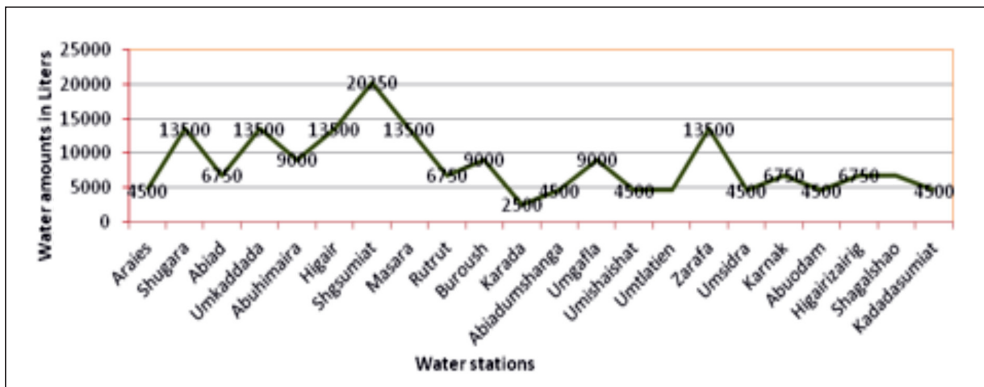


Fig.5: Hourly water production by water stations in Umkaddada locality in liters

In Toaisha (Fig.6), the highest production per water station was 33,750 liter which equals 33, 75 m³, and was recorded in one location representing 6% of the total number of water stations in Toaisha (Fig. 6). On the other hand, the lowest production per water station was 2,250 liter which equals 2.25 m³, and was recorded in two locations representing 12% of the total number of water station there. These statistics give average water production of 5.2 m³ / h (5,202 liter / h) and the standard deviation of 7.4 m³ / h which equals 7,447 liter / h (table 2), and range value of 33,750 liter which equals 33.75 m³. The range value indicates wide differences between water stations which might depict wide discrepancies in water production in Toaisha (Fig.6).

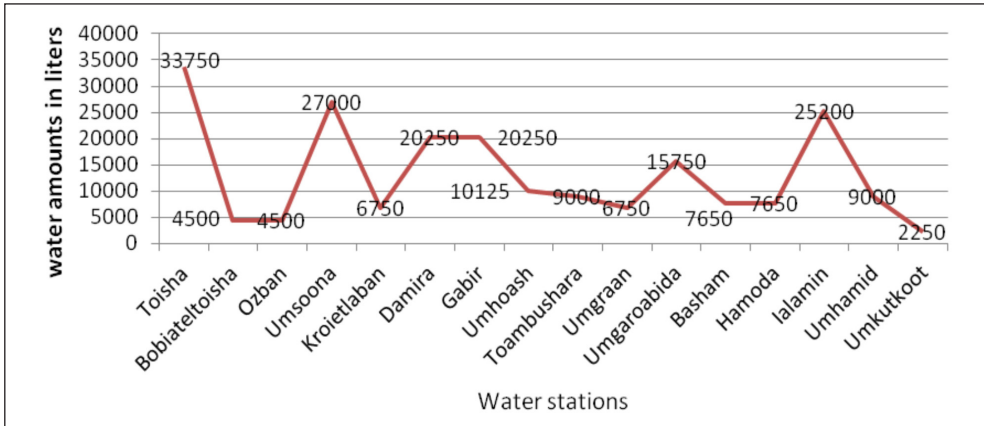


Fig.6: Hourly water production by water stations in Tolasha locality in liters

In Laitgarelnabi (Fig.7), the highest production per water station was 20,250 liter which equals 20.25 m³, and was recorded in two locations representing 7.7% of the total number of water stations in Toaisha (Fig. 7). On the other hand, the lowest production per water station was 9000 liter which equals 9 m³, and was recorded in eleven locations representing 42% of the total number of water station there. These statistics give average water production of 4.5 m³ / h (4,500 liter / h), and the standard deviation of 7.5 m³ / h (7,573 liter / h) (table 2), and range value of 11,250 liter which equals 11.25 m³. The standard deviation and range values indicate wide differences between water stations production in Laitgarelnabi (Fig.7).

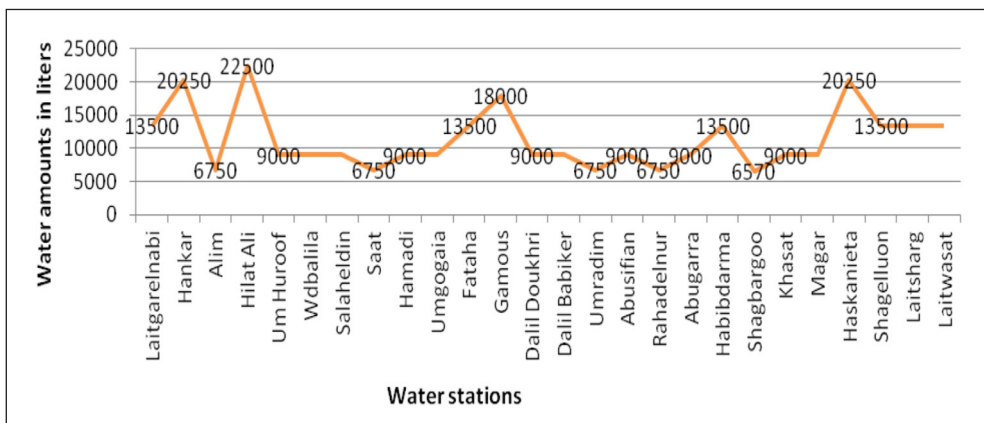


Fig.7: Hourly water production by water stations in Laitgarelnabi locality in liters

Water stations separately, contribute annually by 514,966 m³ (table 1). This amount was distributed as 344,250 m³ in Umm Kedada (66.8%), 76,934 m³ in Toaisha (14.9%), and 93,782 m³ in Laitgarelnabi (18.2%). Grouping of water production by water stations for whole the study area (table 2) gives average (\bar{x}) production of 12.3 m³ /h (12,303 liters /h), and standard deviation (σ) of 6,615 liter/h (6.6 m³/ h) (table 2). The big difference between the mean and standard deviation reveals wide geographic difference into water production per water station, which was further indicated by the range value of 31,500 liter (31.5 m³).

Geographic comparison shows that, water production in Umm Kedada was on average less by 2.0 m³ / h (2,034 liter / h) than that in Toaisha and was further less by 1.3 m³ /h (1,332 liter /h) than Laitgarelnabi (table 2). This means that water production in Toaisha exceeds Umm Kedada by nearly 64% and Laitgarelnabi by nearly 30%, though number of water stations in Toaisha is less than those in Umm Kedada and Laitgarelnabi. This might due to the big number of non-operating water stations in Umm Kedada relative to both Toaisha and Laitgarelnabi. Moreover, water production by water stations agrees on wide geographic discrepancies at the station level. The big difference between the values of the mean and the standard deviation in Umm Kedada (table 2), indicates to wide discrepancy in water production per a water station which is somehow reversed by the same statistics for Toaisha and Laitgarelnabi (table 2). This indicates to close level in water production between water stations in Laitgarelnabi compared with Umm Kedada and Toaisha which might be referred to adequate discharge of the aquifer during the rainy season which might be reflected into water stations productions.

Table 2: Grouped data of water production by water station by locality in eastern Darfur (in m3)

classes	Umm Kedada (f)	Toaisha (f)	Laitgarelnabi (f)	Total Frequencies (f)	Class Interval (c)	c x f	deviation from arbitrary point of origin (d)	f x d	d ² f
2.25-4.5	0	2	0	2	3.3	6.6	-0.05	-0.1	(5.1)
4.5-6.75	5	1	0	6	5.6	33.6	-0.03	-0.2	(1.7)
6.75-9.0	5	4	5	14	7.8	109.2	0	0	0
9.0 – 11.25	3	2	11	17	10.1	171.7	0.01	0.2	(0.6)

11.25– 13.5	1	0	0	1	12.3	12.3	-0.05	-0.05	(0.7)
13.5-15.75	5	0	6	11	14.6	106.6	-0.01	-0.1	(53.9)
15.75-18-0	0	1	0	1	16.8	16.8	-0.05	-0.05	(0.7)
18.0-20.25	0	0	1	1	19.1	19.1	-0.05	-0.05	(0.7)
20.25-22.25	3	6	3	12	21.3	255.6	-0.03	-0.05	(0.05)
Total	22	16	26	64		787.5		-105	63.8
Umm Kedada: \bar{x} = 3.1 m ³ /h (3170 liter/h), σ = 7.4 m ³ /h (7461 liter/h) Toaisha: \bar{x} = 5.2 m ³ /h (5202 liter/h), σ = 7.4 m ³ /h (7447 liter/h); Laitgarelnabi: \bar{x} = 4.5 m ³ /h (4500 liter/h), σ = 7.5 m ³ /h (7573 liter/h)									

Water consumption

Waters are used for human and animal consumption. Population number was estimated at 206,020 in the year 2000 with an annual percent of increase of 3% to reach 267,820 in 2010 (Fig.8). This is accompanied by an annual percent of increase of animal population by 3% to reach 2,524,307 in 2010 instead of 1,941,987 in 2000 (Fig. 8). Local water authority estimates per capita per day water consumption at 18 liters (0.018 m³), while for animals it was estimated on average at 22.5 liters /head per day which equals 0.022 m³, allocated as 27 liters for a cow and a camel, 18 liters for a horse and a donkey, and 13.5 liter for a sheep and a goat. The calculation of per caput per day water consumption for human population gives 4,811,040 liters/day (4,811 m³) which equals 1,735,473,600 liters /year (1,735,473 m³), while for animal population it culminates to 56,796,907 liters / day (56,796 m³) or 20,446,886,700/ year (20,446,886 m³). The estimated daily consumption by both populations is 61,607,947 liters/ day (61,607 m³) which equals 22,178,860,920 liters / year (22,178,860 m³). Animal consumption exceeds human consumption by 18,714,912,120 liters annually (18,714,912 m³) which equals 98% of the total water production in the study area. This indicates that, only 407,366,000 liters were left for human population which equals 2% of the total production. But animals staying away for some months of the year makes water surplus for people.

This estimated daily consumption by water authority in the study area is far less than the daily recommended level for an individual to remain healthy, as it stipulated 40-50 liters (0.04 - 0.05 m³) per day per person is adequate by

WHO (1983). This means that human population in the study area should be daily allocated by an amount of water as high as 13,391,000 liters (13,391 m³) or 4,820,760,000 liters annually (4,820,760 m³, or as low as 10,712,800 liters (10,712.8 m³), or 3,856,608,000 liters annually (3,856,608 m³). There is a difference between what was daily allocated by local authority and was daily recommended by WHO (1983) as high as 8,579,960 liters (8,576.9 m³) or as low as 5,901,760 liters (5,901.7 m³). This means that, the amount of water allocated to human population should be tripled to meet with the higher level of 50 liters, or doubled to meet with the lower level of 40 liters recommended by World Health Organization (1983). However, balancing total water production with these highest and lowest levels recommended for human population by World Health Organization, give a surplus of 16,033,493,000 liters (16,033,493 m³) for the highest level, and 16,997,645,000 liters (16,997,645 m³) for the lowest recommended level. The study area is potentially producing adequate water to meet with the highest recommended amounts of water recommended by World Health Organization, but the inclusion of animal population gives a different scene of water shortage.

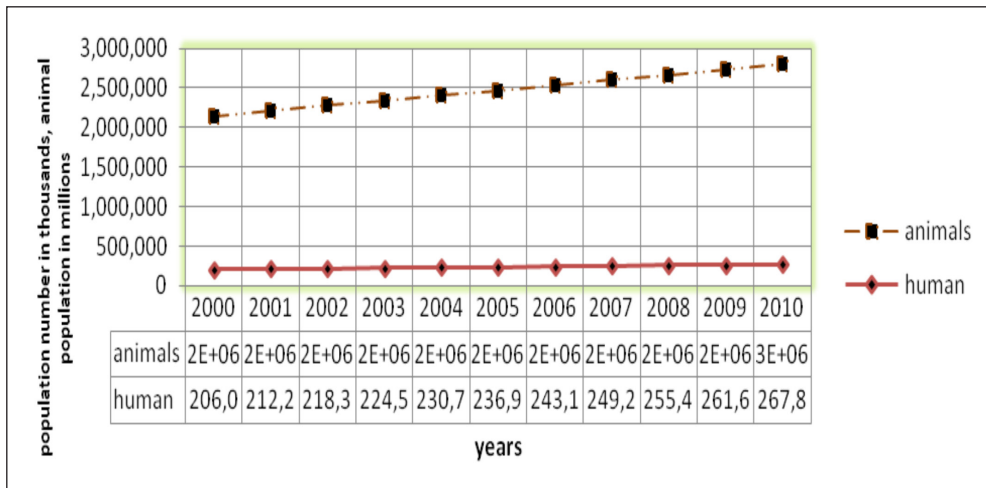


Fig.8: Human and animal population in eastern Darfur: 2000-2010

Water is priced by the Rural Drinking Water Corporation at 2.50 Sudanese Guinea per water tin which equals 4 British Gallons or 18 liters (0.018 m³). This means that a family of six persons in the study area has to pay 15

Sudanese Guinea daily, which equals five USD, to meet with the minimum amount of water allocated by local authority. This gives a monthly sum of 450 Sudanese Guinea (150 USD) and annually 162,000 Sudanese Guinea (1800 USD). However, a family in a home - piped third class residential areas in Khartoum town, pays monthly 15 Sudanese Guinea (5 USD) or annually pays 180 Sudanese Guinea (60 USD). This means that a rural household in the study area pays thirty times to buy water compared with any urban household. People will, of course, reduce their consumption; look for free of charge water sources, store rainwater or fetch water from far distant sources.

Projections under climate change scenario

Climate change in the study area could be shown with reference to change in the characteristics of the rainy season. The nearest longstanding rain gauge, which is more representative of the southern part of the study area, is at Ed Duiem and suggests a long-term average annual rainfall of 285 mm (1902-1990). Since the 1950s the average rainfall has fallen sharply due to severe drought from 1968 to 1972 and again in the 1980s, with 1984 being the driest year on record. The mean rainfall for 1965-84 was 214 mm, 40% lower than the 365 mm seen from 1920-39 (Walsh, 1991). The decade 1981-90 was 35% below the mean of 330 mm for 1920-50. Based upon figures available there seems to be little evidence for significant improvement since 1990 (Alredaisy and Davies, 2000). Rainfall figures in the 20th century suggest that the 1930s saw a peak in rainfall and that since then rainfall was generally in decline until the mid-1970s, when it appears to have leveled out at about 250 mm. These findings illustrate geographic and temporal variations in water production and consumption, as well as managerial problems. The reasons for such variations are, environmentally, socio-economically and geographically related. The whole of the study area is characterized by climatic conditions conducive to water shortage. The effect of climate change and global warming are evident in the study area as it has been designated by the United Nations as under “very high risk” of desertification (UN, 1977). This had seriously caused many dramatic changes by disturbing the rhythms of grazing, cultivation, and migration and so compete with livestock for both land and water (Alredaisy, 2012). Under this climate change conditions, shortage in water production is expected, which will be more exacerbated by increasing demand.

Water budget for each locality

As stated earlier, various water sources, excluding rainfall, contribute into the total annual water budget of the study area which is estimated at 20,854,253 m³ annually, distributed as 514,966 m³ for water stations; 277,483 m³ for surface wells; 55,496 m³ for hand pumps; and 27,748 m³ for hafirs; and 54,000 m³ for British Childhood Care organization contributes; and 19,978,560 m³ other nongovernmental organizations. The study took water production by water stations in each locality as index to determine water budget in each locality due to lack of data concerning numbers of other water sources. Water stations produce 344,250 m³ in Umm Kedada, 76,934 m³ in Toaisha, and 93,782 m³ in Laitgarelnabi (table 1). The total population in Umm Kedada is 150,000, in Toisha is 50,000, and in Laitgarelnabi is 67,000 according to estimation in 2010. The number of animal population is 1,250,000 in Umm Kedada, 980,000 in Toisha, and 402,307 in Laitgarelnabi. Based on local water authority estimates for water consumption for per capita per day at 18 liters (0.018 m³) for human, and 22.5 liters / head per day (0.022 m³) for animals, water budget for each locality is determined.

Umm Kedada water budget: 344,250 m³ annual production, human consumption 2700 m³ /day (annual = 972,000 m³) + animal consumption 27,500 m³ /day (annual = 9,900,000 m³) = total = 10,872,000 m³. Deficit = 10,872,000- 344,250 = 10,527,750 m³. Toisha water budget: 76,934 m³ annual production, human consumption 900 m³/day (324,000 m³ /year), animal population 21,560 m³/day (7,761,600 /year) = total = 8,085,600 m³. Deficit = 8,085,600-8,008,666 m³. Water budget in Laitgarelnabi: 93,782 m³ annual production, human consumption 1,205m³ /day (434,160 m³ /year), animal consumption 8,850 m³ /day (3,186,271 m³/year) = total = 3,620,431 m³. Deficit = 3,620,431 m³ - 93,782 m³ = 3,526,643 m³.

Other sources of water, of course, contribute in the water budget, but the general scene confirms water deficit of water to meet demand. Projected conditions for future demand of water for whole east Darfur is provided by Abdo and Salih (2011). They estimated that, future demand for human will be 48 MCM/y in the year 2020, and for animal it will be 34.2) MCM/y. This is compared to 31.7 MCM/y for human and 28.1 MCM/y for animal in 2010.

Water quality

Assessment of water alkalinity was estimated at 70 parts per million (ppm) at Bahr el Arab water divide (Water Authority, El Fashir 2010), which is acceptable for domestic use according to World Health Organization which puts less than 100 part per million (WHO, 2009). In the middle of the aquifer, it equals 2500 ppm with an average of 400 ppm (Water Authority, El Fashir 2010), is not desirable for drinking water, and the average of 400 ppm is desirable for drinking water as World Health Organization puts the range 30-400 part per million (WHO, 2009). Chemical assessment of water produced by water stations in Umm Kedada gave 200 mg/L chloride; 100 mg/L calcium. In Laitgarelnabi, similar assessment gave 400 mg/L chloride; 300 mg/L calcium. Chloride level in Umm Kedada (200 mg/L) is acceptable since it is close to 250 mg/L recommended level by World Health Organization; while in Laitgarelnabi chloride (400 mg/L) exceeds 250 mg/L recommended. For Calcium, Umm Kedada (100 mg/L) exceeds the lower recommended level of 75 mg, and is far less than the higher recommended of 200 mg; and can be considered less than desirable. For Laitgarelnabi, Calcium level of 300 mg/L exceeds high levels of 200 mg/l and can be considered hard. The general picture is that, water in Umm Kedada is chemically advantageous than Laitgarelnabi.

Per caput per day consumption of water in the study area is far less than the international standards and was even more exacerbated by low chemical properties of water. This makes people of the study area more vulnerable to health hazards when, for instance, excess calcium affects blood channels and lead to hypertension, rickets, and kidney diseases (WHO, 2009). Water shortage in the study areas make people vulnerable to infectious diseases. This is confirmed in Darfur by the study in Kas town in northwest Darfur (El Bushra and Alredaisy, 2011). Vulnerability to water related diseases was further exacerbated by high cost to purchase water in the study area, although the only major item in their household budget which can be sacrificed to make this possible is food. This will, of course, reduce the share of a member in a household in the total budget devoted to buy other life needs. This is similar to what had been found in Karton Kassala squatter area in Greater Khartoum, Sudan, where 56% of total household income was spent for water purchase (Sandy et al, 1992). These features occur in many other rural areas

of Sudan and are typical of areas where there are low incomes and much poverty (Smith et al. 1979; Zeitlin and Wray 1982; World Bank 1990).

Water quality can be detected by chemical assessment and the presence or absence of pathogenic organisms. The presence of fecal matter in water presents the most immediate hazard to health and if water contains more than 10 coliform 1 Escherichia Coli per 100 ml of water it is considered contaminated and unsuitable for human consumption (WHO, 1983). Chemical assessments include, among many, detection of heat (temperature), alkalinity, acidity, chloride, calcium, ferrous and electro-conductivity. Calcium plays an important role in bone structure and body metabolism and the recommended daily intake is 75-200 mg/L, though recommended intakes for a specific age and/or sex group can vary widely (WHO,2009). The recommended level of chloride is 250 mg/L (WHO, 1984). Water that contains more than 200 mg/l as calcium carbonate is considered to be hard and may cause plumbing and laundry staining problems. Hardness measures (expressed in mg/l) include 0 - 100 Soft, 100 - 200 Moderate, 200 - 300 Hard, 300 - 500 Very hard, 500 - 1,000 extremely hard (WHO, 2009). Chloride concentration above 250 mg/l can produce a distinct taste in drinking water. The levels of chlorides are expressed in mg/l to include 0 - 250 acceptable, 250 - 500 less than desirable, 500 - 1,000 undesirable, over 1,000 unsatisfactory (WHO, 2009). For ferrous, 0.3 mg/L were recommended and levels of iron (Fe) which are expressed in mg/l: 0 include 0.3 acceptable, 0.3 - 1.0 satisfactory, over 1.0 unsatisfactory. Water alkalinity is useful since it acts as a buffer against changes in pH where its international standard is recommended in the range 6.5 – 8.5 (WHO, 1971). The pH of drinking water normally ranges from 5.5 to 9.0. Alkalinity concentrations less than 100 part per million, are desirable for domestic water supplies. The recommended range for drinking water is 30 to 400 part per million (WHO, 2009).

Water management

The Rural Water Management Authority began as a part of the Department of Public Works. In 1960, it came under the authority of the Council of Provinces, then the Rural Water Authority, and finally the Drinking Water Provision Corporation. This led to conflicts of interest between civil administrative officers and technical engineers. Furthermore, financial affairs concerning water stations were under the responsibility of local government

instead of Drinking Water Provision Corporation. In 1983, the Peoples' Committees were formed to manage water stations through self-cooperation. They were developed into Committees of Rural Water Stations Administration. Due to the failure of these committees to manage water stations, each administrative locality issued its own water tariff to overcome financial difficulties. This has resulted in wide geographic discrepancies into water prices in the study area. Under these deteriorating conditions, the Administration of Drinking Water was established in 1997, in collaboration with local Administration, to organize rural water satiations with particular reference to maintenance and financial supervision. A local committee was formed for each water station, including head of the committee, the station clerk, and station water engine Oiler; head Police Officer and the nominated Peoples' committee. At the locality level, coordination committees were responsible for coordinating between Peoples' Committees and Water Administrations. The water station clerk is responsible of the station's financial affairs, payment of taxes imposed by the locality, and assignment of fuel bills. The earning from water sales was divided as 40% goes to the Water Corporation to pay salaries, and spare parts and fuel bills and 60% goes share to the Peoples' committees to buy also spare parts and fuel.

According to the water technical staff in the in the study area, water stations are faced with chronic shortage of spare parts, high fuel costs, and low earnings from water sales, as well as the incapacity of the facility installed to withdraw the water from the water source. In addition, the majority of the water stations were dug in remote areas, and there is chronic shortage in trained technical staff, administrators, Oilers, and automotives. Most of the water stations have not been adequately studied; lack adequate continuous or periodic data collection; organization and analyses of data and information for purposes of effective management. The continuous change of the administrative committees have opened a window for money corruption, particularly when these committees hold the responsibility to collect money from direct water sales, purchase of fuel and spare parts or pay salaries to the working staff.

NGO's began rehabilitating water sources in 1991 through the Sundous Cooperative Project, which aimed to raise the standard of living, provide adequate and safe water, improve general hygiene, and develop human

resources. Their efforts included the establishment and rehabilitation of water stations, hafirs, water storage tanks, surface wells, hand pumps and building capacity of local communities into water projects management. Ngo's have adopted participatory approach into planning and implementation of water projects. This included problem analysis, specification of needs and priorities, project planning, project funding, follow up and evaluation. When implementing and funding the project, an agreement was assigned between beneficiaries and local authorities to determine responsibilities of each side. The responsibilities of the nongovernmental organization were studying geographic potentiality of an area with collaboration of local people and official authorities to determine needs and priorities, payment of 50-80% of the project cost, technical supervision, training of administrative committees and project following up. Beneficiaries pay 20-50% of the total cost of the project; provide manual labors, administrative supervision, following up of manual works, and appointment of administrative committees. Special attention has been paid to training of human resources and building capacity of beneficiaries in order to manage their water projects effectively when these organizations leave the study area.

Nongovernmental organizations have successfully trained administrative committees on management of water stations, collection of money, follow up and evaluation and water uses, organizing meetings, taking decisions and writing reports. In the technical side, they have trained the committees' members on operation and maintenance of hand pumps; building of surface wells, daily routine works of engines checking and replacement of spare parts and installation of new water pumps. Ngo's have also provided highly efficient and productive manual pumps; spare parts; which adequately improved water production, and increased money earnings from water sales, decreasing time spent by local people into water fetching. In addition, diesel pumps were replaced by solar energy pumps in some water stations which have reduced costs of operation and maintenance and water tariffs. In addition, nongovernmental organizations have participated into designing of water stations, and organized the access of animal to water source to avoid health hazards to human population; and established plant nurseries in the water stations to benefit from disposed flowing water. Managerial problems were inherited since the initiation of the borehole drilling program to combat thirst in western Sudan in early 1970s. They might reflect the neglect of rain

lands in the general process of development in Sudan, partly because of the large investment sum which would be necessary to provide an adequate infrastructure of water supplies, roads and marketing in such areas (Alredaisy and Davies, 2001), similar to a situation that has been noticed in Mauritania (Knerr, 2001). This contrasts central Sudan, particularly between the White and Blue Niles, which formed the core of Sudanese economy, because Condominium and post-independence governments believed that the future of Sudan economy lies in commercial agriculture and has failed to provide any development strategy for the traditional peasant sector which holds the majority of Sudan's population (World Report, 2001). It was evident from our results that, NGOs intervention has improved these water stations, particularly the technical side. This indicates that, few efforts will improve these water stations as it happened in South Africa (www.62.co.za. 2011) and Ethiopia (Zinabu, 1988).

The Proposed Axes of an integrated management plan

The proposed plan includes eight axes (Fig.9). The first axis is careful assessment of the area's carrying capacity of human and animal populations; the second is the consideration of environmental planning with development planning; the third is the local environmental legislations; and the fourth axis is that rain lands to be looked at as single entity for development policy; the fifth is the agricultural produce for domestic household use, the sixth is the pasture development for redistribution of livestock; the seventh is the participatory approach to water management; and the eight axis is the coordination system of water management.

Careful assessment of the area's carrying capacity of human and animal populations will determine the sizeable distribution of both populations to avoid over pressure on water sources and pastures. Geographical data is important and will provide information on location, population mobility and density, congestion, and geographic proximity and their impacts on water sector that could help in the establishment of water resources monitoring and information system. The presence of an adequate water monitoring and information system is a pre-requisite for any successful management of water resources system. The result revealed that this system is almost absent or minimal in the study area and suffered huge degeneration as a result of

economic and political instability. In its strict sense provide adequate information for purposes mentioned above. Monitoring requires regular observation and coordination of information on water use data, socioeconomic data, supporting remote sensing data, knowledge base, capacity development issues and linkages to other relevant data bases.

Integrating environmental planning and development planning will equilibrate water resource utilization and the environment conservation that will secure water resource sustainability. Geographical data is also important as it include information on location, population mobility and density, congestion, and geographic proximity and the role of these factors in exacerbating water problems. Water problems have geographical scales and determination of such geographic differences in water issues provides a spatial database for dealing with water problems.

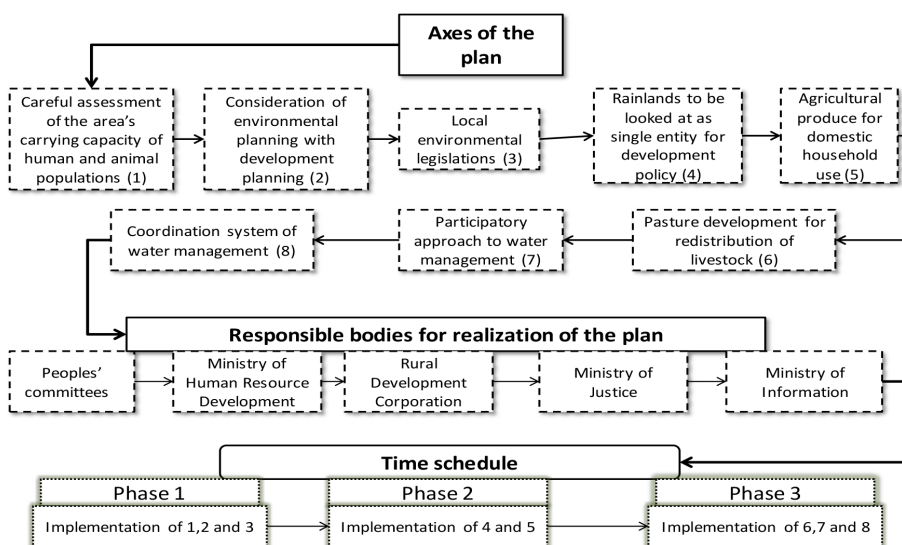


FIGURE 9: Plan to alleviate water management problems and promote water use in Eastern Darfur

Local environmental legislations should consider environment conservation and community demand relations, i.e., they have to equilibrate resource utilization and resource conservation to guarantee resource and environment sustainability. In addition, rain lands have to be looked at as single entity in development policy of Sudan. This is because of their fragile environment

where water temperature, rainfall, or aridity determine water availability and seasonality and affect the community situation.

It is no longer economic to produce rain lands crops in eastern Darfur for market purposes and therefore agricultural produce for domestic household use and it would seem to be better suited to livestock rearing. This might reduce water conflict as more water would be available and accessible to livestock. Nonetheless, pasture development for redistribution of livestock is essential in this proposed plan because this achieves equal distribution of animal wealth and works to avoid animal pressure on water sources.

Participatory approach, through Peoples' Committees in the proposed plan, is important in the assessment and reduction of risks of water shortage. A participating community will, of course, have knowledge about water value, water conservation, and water rights for oneself and others, as well as the impacts of environmental degradation on water sources. In addition, social capacity building through participatory work and civil or voluntary organizations can work to assess water problems and help to alleviate them. Environmental education via media will, of course, diffuse awareness on ways of proper water management. However, coordination system of water management will offer an effective method of conserving the hydrological regime in the study area, and maximizing the benefits from its water resources.

Discussion

This study depicts that, the study area lacks careful assessment of the area's carrying capacity of human and animal populations in order to sustain water resources through even distribution of water stations, hafirs, and Rahads. This has, in particular, influenced appropriate management of water resources due to heavy concentration of animals and herders during dry season in some environmentally fragile parts of the region. Determination of rainfall potentiality to support pasture carrying capacity of animals was completely ignored in situations of erratic and fluctuating rainfall. Introduction of careful assessment of the area's carrying capacity of human and animal populations will, of course, improve management of water resources in this region, but requires geographic database, financial funds and technical staff to do research on plant species, soil physical and chemical properties, types of animals and their water needs throughout various seasons of the year, as

well as socioeconomic and demographic characteristics of communities distributed within the region. Though some of this information might be available by entitled governmental departments, they were not put into benefit for assessment of the area's carrying capacity of human and animal populations. .

The study area lacks integrating environmental planning and development planning, which have led to deterioration of natural vegetation, sand encroachment southwards, and pushing of farmers and herders to areas with adequate pasture and water in southern parts of the region. Also, this has caused pressure on water sources and pastures with consequent climatic impacts. And to overcome these climatic impacts on water, and to correspond with population growth, expansion of water stations through the government's hafir digging and borehole drilling program in early 1970s had led to the expansion of occupancy in these dry lands. This is similar to the pastoralist communities in the north and north-eastern Kenya (Actionaid.2011) and the Sahel region in Niger (Woodke, 2007). Rural water provision has been expanded dramatically without sufficient thought with reference to development planning, where dispersion of water stations in the study area, was quite irregular. These water stations provided a little guaranteed source of water supply, leading to more permanent settlement, but at the same time, brought to an end the traditional symbiotic relationship between water supply, people, animals, and vegetation. They have effectively cut off the traditional pattern of animal grazing and watering whereby in the later dry season flocks and herds moved down to graze the lands uncovered by natural vegetation and without adequate water supply (Davies, 1987). This is similar to many other areas of western Sudan, and West Africa (Cour and Snrech, 1998), and agrees with Lange's notification (1985) that animal and human demand for water can't be balanced in such dry lands when there were large numbers of animals and few water points, as well as inappropriate management of water sector. In our point of view, introduction of this axis in management of water resources in this region will doubtlessly, alleviate all these shortcomings.

Local environmental legislations to prevent overexploitation and overutilization of water resources were not integrative part of managing water resources in the study area. Herders can keep as much as livestock, irrespective of grazing and watering potentialities. Similarly, farmers can open lands for

cultivation in areas suffer inadequate rains. In addition, no penalties are imposed on violation by farmers who cut off routes and trespasses onto reserved areas in order to deter nomads and to use the reserved areas for agriculture, and interfere with water supplies created to assist conflict – free passages of nomads along designated routes, or destroy hafirs which were constructed to provide water for livestock to discourage grazers and diverting the stored water for cultivation, and destroy some other hafirs constructed for human consumption because nomads were attracted to them and were providing a nuisance to local farmers. However, introducing environmental legislation water management is essential.

The rain lands of the study area were not looked at as single entity in development policies of Sudan. These development efforts did not commensurate with the fragility of its environment, concerning the distribution and utilization of water resources and their efficient management. The water sector lacks a master plan to organize human and animal demand for water. This study revealed that, animal population consumes more water compared to human population which contributed in water insecurity in the study area. In addition, these development plans did not consider water conservation during rainy season through introduction of water harvesting methods or to educate local communities how to use water sources rationally. Nomads' movements during dry season, and the pressure they cause on water were not, also recommended by these development policies. In addition, development planning did not put into consideration that, it is no longer economic to produce rain lands crops in eastern Darfur for market purposes and therefore agricultural produce should go for domestic household use. Huge areas were cultivated by cash crops which cut huge areas used as pastures for livestock and reduced water availability for nomads and animal owners. Lacking coordination between what was devoted to cash crops for export and what was devoted for pastures and food crops had created competition over shear water sources and to open more lands in the northern environmentally fragile parts of the region. This competition has created managerial water problems to control farmers, animal owners and herds, and settled people. Introduction of this axis is essential to contribute into efficient management of water resources in this region.

This study revealed that, pasture development for redistribution of livestock,

as a policy for management of water resources was not emphasized in this region. Redistribution of livestock accompanied by conservation and rehabilitation of pastures were not integrated in this region. Creation of conserved or protected pastures to access water sources is also absent. However, there was no participatory approach for local community capacity building in the study area. Though some efforts were exerted to enhance Peoples Committees to manage water stations, but were not emphasized. Participatory activation was mainly enhanced by NGOs, while governmental water and administrative authorities have failed to do that. This confirms for an opportunity to enhance the community to participate effectively into water sector management. This makes the introduction of this axis by our plan essential for good management of water in this region.

Though it was found from this study that, there are many water resources, it must be emphasized that these resources require a coordination system of water management and sound governance, in addition to a great deal of financial and human resources to make them substantially available for various uses. The old approach business as usual has led to huge conflict between the various users, particularly the farmers and the animal owners over abstraction and quality deterioration of the readily available water resources. More work is needed in tools such as water harvesting, developing non-renewable water resources and managing demand as well as implementing the practice of conjunctive use of rainfall, Wadi flows, and groundwater. These could be successful with sound governance at all levels, local, state and federal. Sound governance requires transparency, equity, ethical behavior and sense of ownership at all levels. This is particularly important for the study area where the role of users in decision making, is relatively lower but the existing water resources are often threatened by depletion and competition.

Bodies responsible for implementation

The plan consists of five major responsible bodies for realization of the plan. The five major responsible bodies proposed to implement the plan, include Peoples' committees; Ministry of human resource development; rural development corporation; Ministry of Justice; and Ministry of Information. Realizing this proposed plan depends on collective work by these bodies identified in Figure 9. The duties of People's Committees should focus on

transferring information to local communities on innovative directions for water utilization, ways of rational use of water sources and the impacts of misuse as well as health hazards related to water, through youth clubs, and religious men and women in those communities. Ministry of Human Resource Development should train local people on how to rationally use and manage their water resources through Integrated Water Resources Management (IWRM) where community education for sustainable development (ESD) is essential. Methodology for implementing ESD should firstly, target stakeholders who could be middle leaders, including executive committee of local non-governmental organization, local public committee and official officers and teachers. Awareness creation is a step towards drawing attention and building capacities of the stakeholders to deal with the challenges of water resources. Through increased knowledge and awareness, the community can be motivated to take better care of their water sources. School teachers should be trained on environmental education, particularly in primary schools. Introduction of education for sustainable development (ESD) into schools' curricula, students' activities, mass media and youth clubs will inform the community on rational water use. This could be more enhanced by Rural Development Corporation that should adopt water sustainability initiatives at community level which requires the involvement of local communities including men and women. Women are important target group, as they play a significant role in rural family life and have a prominent role in improving the use of water within the family. The Ministry of Justice could protect any water policy through legislations on water use and management and could also execute penalties on misuse of water or on corruption in the water sector. But, this cannot be accomplished without the role of Ministry of Information. The motivation of the community to maintain and protect their water source is of critical importance to ensure a sustainable reduction through TV, Radio, and Newspapers which can transfer knowledge about water production, distribution and water legislation as well as any innovative directions concerning water utilization, where for example, strengthening rain water harvesting networks will promote knowledge of good practice and endeavors to disseminate such understanding.

Time of implementation schedule

The implementation of this plan needs to be phased in carefully. It consists of three phases to implement the proposed eight axes. Phase one concern with

the first three axes; phase two concerns with axes four and five, while phase three concerns with axes six, and seven and eight (see Figure 9). In the first phase, it is necessary to provide careful assessment of the area's carrying capacity of human and animal populations; consideration of environmental planning with development planning; and local environmental legislations. In the second phase, rain lands have to be looked at as single entity for development policy, and agricultural produce should be devoted to domestic household use. In the third phase, coordination system of water management; participatory approach to water management; and pasture development for redistribution of livestock should be integrated. In addition, coordination between governmental bodies responsible for water provision and management with reference to local community is essential. Participatory approach, through Peoples' Committees is important in the assessment and reduction of risks to water shortage. A participating community will, of course, have knowledge about water value, water conservation, and water rights for oneself and others, as well as the impacts of environmental degradation on water sources. In addition, social capacity building through participatory work and civil or voluntary organizations can work to assess and alleviate water problems through innovative directions, such as water harvesting, for water utilization in the study area. Participatory approach is especially desirable, as proved successful by the experience of nongovernmental organization in the study area. Moreover, pasture development for redistribution of livestock would require a coordinated system of range management with careful assessment of range carrying capacities that will reduce pressure over water resources used. Changing the composition of the herd by shifting to animals with low water consumption, may be sheep, goats, and camels, excluding cattle and changing the society view towards animal quality rather than quantity will relieve pressure on water resources and provide additional water for people. This can be enhanced by construction and maintenance of rainwater reservoirs in the neighborhood.

Challenges to implementation

The major strengths of this plan are its simplicity, its potential to deal with the available water resources at the grassroots level, and its affordability for use with any water problem in this geographic setting. However, the potential challenges one might expect in trying to implement this plan might be political

instability in western Sudan, inflation in Sudan and migration from drier northern parts of Darfur to the study area that might cause overpressure on water resources, as well as rainfall variability. Putting that into consideration, the application of the plan in the study area could be successful. But above all, working towards social and political stability in Darfur is important for maximizing rational use of water resources in situations of changing societies and global warming.

There are many gaps and divides that hinder reliable management of water resources in the study area. The most important of these are gaps in knowledge base and capacity development, absence of comprehensive water resources policy; lack of coordinated decision making at federal, State, and local levels and gaps between decision makers and target groups. There is a gap between researchers, decision makers and stakeholders and bridging this gap is very crucial for sustainable development and management of water resources. This purpose could be achieved by encouraging multidisciplinary research that addresses the interests and motivations of decision makers and researchers and fulfill the needs of the community. There could be enough water resources to meet present and future demands if managed in a sustainable manner considering the closure of the above gaps.

There might be implications of the future events on the plan, particularly climate change and population increase. These two events are interrelated. Since the study area is environmentally fragile and having accelerating increase of human and animal population, their implications on this plan might include deceleration of its implementation, exclusion of some proposed axes and responsible bodies for its implementation or impeded its sequential phases, as well as lack of updated strategies to accommodate current and future changes.

Conclusions

1. A sustainable, integrated water management plan is needed for this region given current and projected water stress.
2. Hydrological conditions, including physical, social, managerial, and projected have been evaluated and a Plan proposed.
3. The plan is awesome because it is comprehensive and deals with grass root society, as well as it adopts the participatory approach for water management.

4. But the plan has weaknesses because it requires financial funds which might be difficult to make available due to inflations and higher expenditure on civil wars, as well as the spread of illiteracy which hinders society involvement into participatory and voluntary works in water sector.
5. As the plan is implemented and continues to evolve the results will be shared with academic community.
6. There is hope, provided there is wise management.

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3

Potentialities of Hydro-Geomorphologic Characteristics of Nyala Valley for Rural Development

Potentialities of Hydro-Geomorphic Characteristics of Nyala Valley for Rural Development

Sudan is virtually striving to optimize its natural resources to speed on economic growth, ease political instability, and enhance population growth and to step into the millennium. These natural resources are varied, among which are the seasonal valleys which own abundant amounts of annually discharged waters. These valleys are mostly of mountainous origin, flashy with extremely high discharge, and are sources of disaster vulnerability. Their hydrological behaviors are controlled by their own geomorphic characteristics and nature of precipitation. ‘Their hydrologic regime is characterized by high variability in temporal and spatial rainfall distributions, flash floods, absence of base flow in most cases, and high rates of evapotranspiration’ (Aboubaker et al. 2019). This research aimed to show these characteristics, as exemplified by Gash and Nyala seasonal valleys, in order to build for rural development in semi arid Sudan via water harvesting programs and reduction of flood disasters.

Rainfall events in semi-arid areas are in general of short duration and high intensity and often characterized by a large degree of spatial heterogeneity (Pilgrim et al., 1988; Wheeler et al., 1991; Martinez-Mena et al., 1998; Lázaro et al., 2001; Wheeler, 2008). These characteristics are even more pronounced in regions with topographic complexity such as mountain ranges (Wilson et al. 2004). Due to the spatial variability of rainfall, runoff is frequently localized while runoff generated in some parts of the catchment may later re-infiltrate and thus do not contribute to runoff at the outlet of the catchment. Runoff may re-infiltrate in the bottom of a valley into a bed of alluvial sediments or become overland flow that may be lost as infiltration into fractured bedrock of channels (Hughes 1995). The infiltrating discharge water contributes to groundwater recharge and the associated groundwater flow in the river valley sediments.

River discharge is the final outcome of a large number of vertical and horizontal flow processes within the whole catchment of the discharge observation point. In semi-arid regions the characteristics of the river flow can be classified as perennial that is flowing all the year; seasonal where flowing only occur in part of the year or ephemeral with extreme flow variability ranging from no flow to flash flood during storms (Lerner et al., 1990). In this

region also, discharge appearing in the upstream parts of the river system may gradually diminish during migration in the river system. This is due to infiltration into the river bed and eventually the flow in the river may disappear completely. Also, overland flow in semi arid areas is categorized into, Hortonian-type of runoff and saturation excess overland flow type, according to the mechanisms responsible for its generation. In the Hortonian-type of runoff high rainfall events exceed the infiltration capacity of the soil and thus leads to surface runoff. (Pilgrim et al. 1988, Hughes 1995). The other type of overland flow occurs when rain falls on land where the subsurface is saturated, which may arise during a rainy period in the bottom of the valley. Another common characteristic is that discharge appearing in the upstream parts of the river system may gradually diminish during migration in the river system due to infiltration into the river bed and eventually the flow in the river may disappear completely. Only during flash floods the river may discharge to the sea. This is particularly true for semi-arid regions where recharge may be as low as 1% of the precipitation (Bouwer, 1989). Furthermore, recharge usually only occurs in limited areas and generally it is non-existent or negligible over much of the semi-arid landscape e.g. at hill slopes. Recharge may occur by various mechanisms, mainly as direct infiltration in flat areas or infiltration from river beds. Additionally, in some formations the excess precipitation is subsequently routed through fractures before discharging into the river or the alluvial material of the lower plains. Finally, the infiltration capacity is also high around vegetation, and conversely, vegetation may only grow where the infiltration capacity is relatively high (Pilgrim et al., 1988).

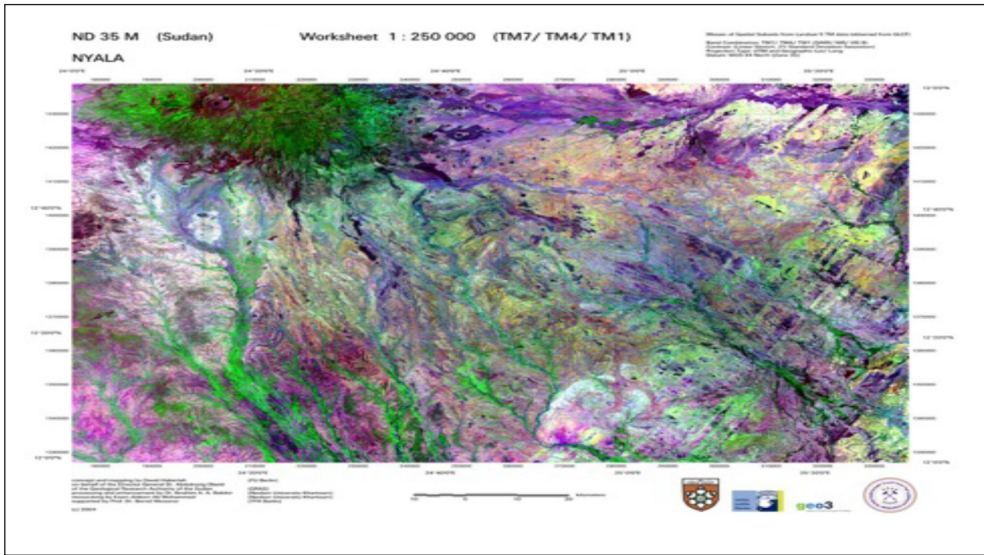
Evapotranspiration is controlled by several factors such as meteorological conditions; characteristics of the surface; canopy; and soil characteristics. In semi-arid regions also, evaporation from bare soil assumes a greater importance relative to transpiration from plants, due to the larger area of bare soil and the frequency of small rainfall events which allow bare soil to return water to the atmosphere without major pathway impedence (Pilgrim et al. 1988). In such regions evapotranspiration captures most of the water entering the soil, and recharge occurs only at extreme rainfall events (Pilgrim et al., 1988). As a result of the spatial variability of landscape characteristics such as geology, topography, soils, land use and vegetation, evapotranspiration will likewise exhibit a spatial variation (Güntner et al. 2004). For hilly and mountainous catchments with a relatively sparse vegetation cover and

subject to high rainfall intensities overland flow generation is frequently occurring (Wheater, 2008). This region's recharge of aquifers may be as low as 1% of the precipitation (Bouwer 1989) and usually occurs in limited areas and generally it is non-existent or negligible over much of the semi-arid landscape.

In semi-arid and arid areas, rain water and flood water harvesting came up in interest in recent decades due to insufficient sources of pumped ground water, reservoirs and streams to meet human and animal demand for water (Prinz 2002). Water harvesting techniques harvest and concentrate rainwater and consequently could increase soil moisture and yields (Mugabe 2004). Infield water harvesting for improved crop yield in semi-arid regions of Zimbabwe has been used to adapt to changing climate since climate change increased vulnerability of crop failure in such areas (Nyamadzawo et al. 2013). In semi-arid Southern African Development Community which is overpopulated and environmentally fragile there are a number of traditional and new and adapted techniques for water harvesting which aim to alleviate the limiting crop production factors (Kronen 1994). In India, several techniques of water harvesting are used in its semi-arid parts for centuries to protect water supplies and to increase agricultural production, and they have been recently promoted (Batchelor et al. 2002).

Study valley

Nyala valley, located at $24^{\circ} 30' - 25^{\circ} 15' E$, and $11^{\circ} 45' - 12^{\circ} - 45' N$, is also a seasonal stream where its upper limit of the catchment lies near the foot of Jebel Merra (Figure 2). Thus the drainage system does not extend onto the slopes of Jebel Merra, in contrary to the neighboring catchments of Wadi Amer and Wadi Bulbul, but is situated in the piedmont area (Lebon and Robertson 1961). The two main branches of Nyala Valley join at Domai, about 8 km upstream from Nyala town.



*Figure 2: satellite image of Nyala valley showing source and direction
Source: GRAS, Geological Research Authority of Sudan, 2010*

Data sources and methods

Geomorphic data for Nyala valley was obtained from Lebon and Robertson (1961), TNO-DGV et al. (1982) and Figure 2, and additionally a recent satellite image based on DEM 90 USGS was processed by GIS Arc-Map 10.5 to produce ordering and lengths of Nyala's basin. Hydrological data for Nyala valley was taken from technical report of TNO-DGV et al. (1985). There were no old continuous records of discharge for Nyala valley similar to that of Gash valley. Relevant Meteorological data for Nyala valley was from Sudan's meteorological Department and some relevant studies.

Geomorphological characteristics of Nyala Valley

Nyala Valley's geology of the catchment (Figure 4) is composed of the quartzite/gneiss formations belonging to the Basement Complex, which are usually at shallow depth. At some places intrusions, mostly granitic dykes are found which form outstanding ridges trending in general between northern and north direction (Lebon and Robertson 1961). The catchment area extends about 90 km upstream of Nyala in north – north – west direction, with an area of approximately 1360 km². The highest elevation of the Nyala Valley catchment reaches approximately 1100 m. The slope is gentle, changing

Nyala valley stream ordering (Figure 5) similar to the Gash valley, reflects an operating semi-dendritic network where first order and second order valleys have formed on steep slopes of J. Marra, i.e. they are the headwater valleys, and also, third order valleys are also headwater valleys. Fourth order could be classified as medium valleys, characterized by less steep and flow more slowly, but tend to have larger volumes of runoff and debris as it collects them from the smaller waterways flowing into them. This dendritic network of Nyala valley is composed of various sub-valleys which differ in their lengths (Figure 6) due to geologic, geomorphic, and hydrologic factors. They eventually contribute into its annual discharge regime.

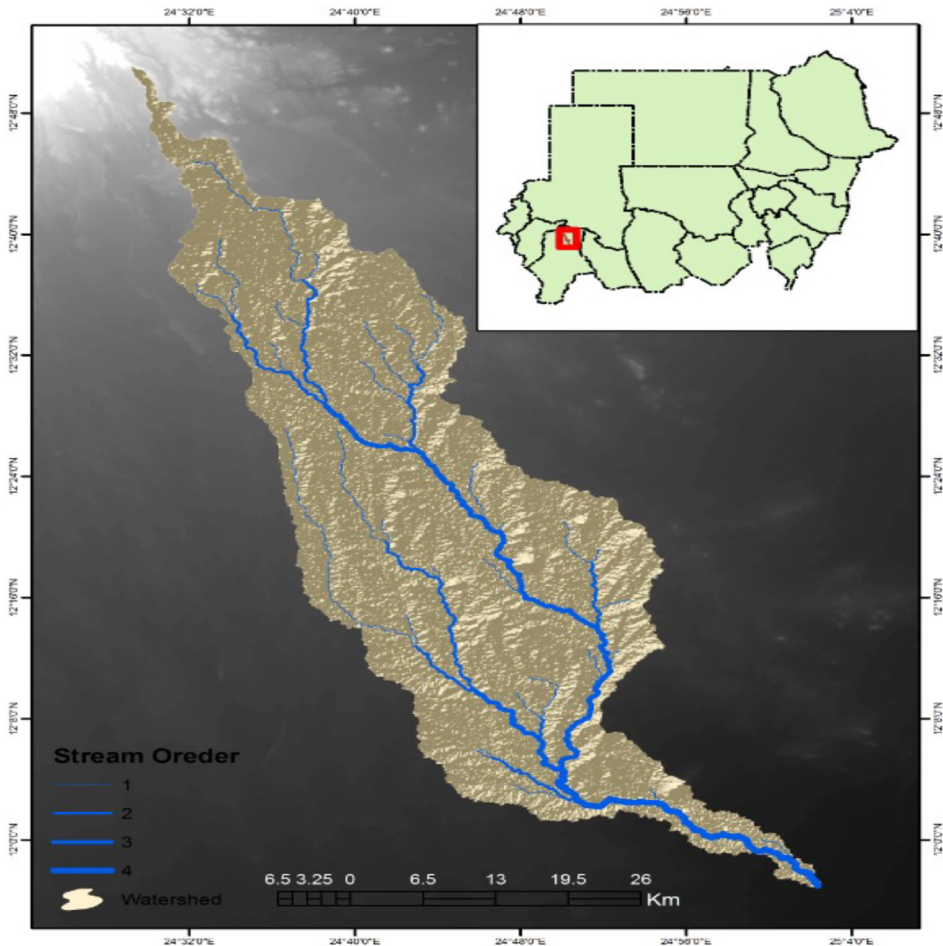


Figure 5: Nyala stream ordering
 Source: GIS Arc-Map 10.5 based on DEM 90 USGS

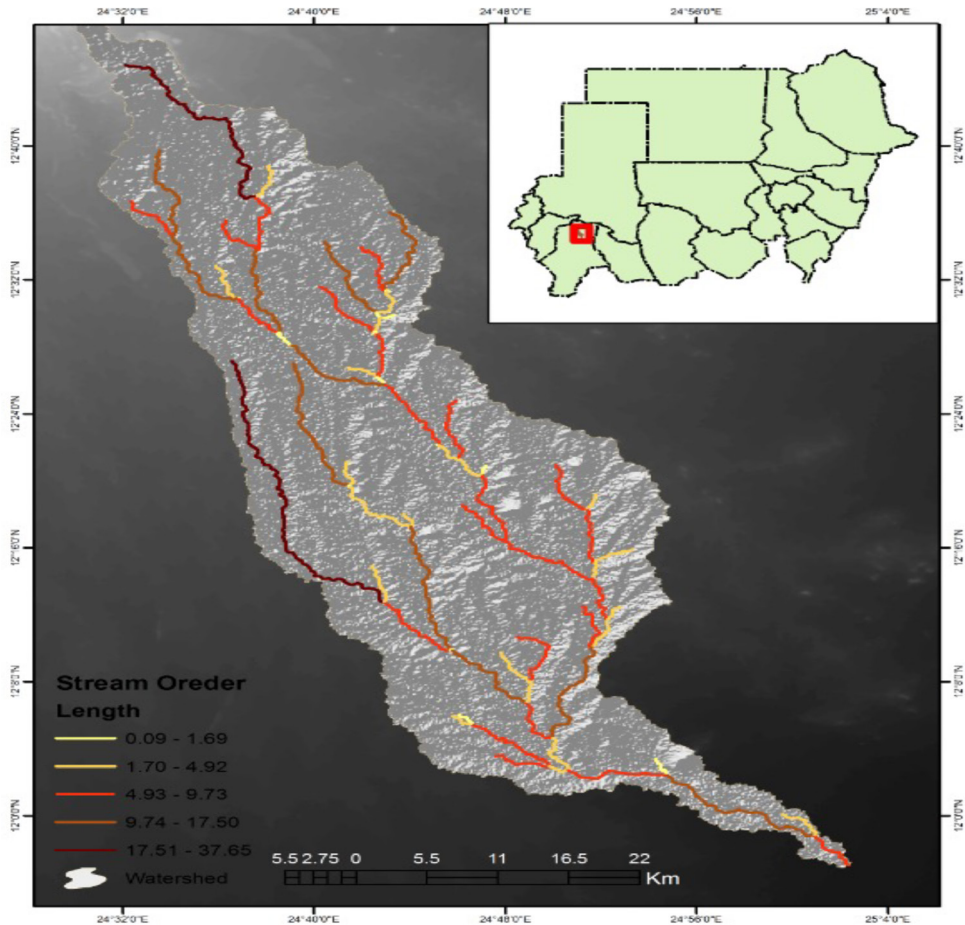


Figure 6: Nyala valley lengths
 Source : GIS Arc-Map 10.5 based on DEM 90 USGS

Rainfall characteristics over the valley

Nyala rainfall station shows strong negative trend of declines in the 1940s or 1950s, which were years of high rainfall. By the early 1960s and that continued through the late 1960s, there was no gradual trend of decline in rainfall (Kevane et al., 2008). For the period 1940–1972, rainfall fluctuated around a stable mean, and for the period 1972–2002 rainfall again fluctuated around a stable but lower mean while the variance of rainfall was the same for both time periods. Simple regression analysis indicated to no statistically significant trend for the two time periods of 1940–1972 and 1972–2002 when considered

separately. Very similar patterns emerged when only looking at duration and begging of the rainy season and for rainfall totals during July–August–September which are strong to the cutoffs in what constitutes descent rainfall (Kevane et al. 2008).

Hydrologic behavior of the Valley

Nyala valley runoff develops quickly soon after rain has started and then the valley is transformed into a wide, wild flowing stream, carrying large quantities of sediment and big logs and sometimes trees float down the river. The tremendous flow velocities (up to 5 m/s) and accompanying turbulences made it impossible to carry out discharge measurements. Under conditions of lower discharges, the maximum flow velocities measured reached 2.4 m/s. The water flows along small drainage channels, which are very densely distributed in a dendritic pattern. These join to form small Wadi's which have a thin sandy bed, but no great lengths. Finally, the water will reach one of the two main branches of the Nyala Valley, the Wadi Kabris and the Wadi Domai. The runoff decreases because of the flooding, but also by the infiltration into the subsurface. In this area the course of the Wadi is sometimes changed after a big flood has passed. As a consequence, the old channel receives less water or even remains dry during the next floods. The valley bed, consisting of loose sands is very unstable, due flashy nature of the floods. The valley is capable of transporting large quantities of sediments and along its course is areas of erosion and sedimentation which continuously shifts after one flood at a certain location, bed levels might be lowered while after the next flood, the deposition of sediment can result in a higher elevation of the bed.

Discussion

Nyala valley is of mountainous origin, flashy with high discharge initiated by similar rainfall influences over most of the Sudan. It is an integral part of the network of Sudanese rivers and valleys (DIU 2009). Sudan is an agricultural country with huge fertile lands and strives to optimize utilization of its share of Nile Water Agreement with Egypt to achieve and accelerate development in riverain areas of central and northern Sudan where Gas and Kassala areas are at a distance. Alternative development efforts could target developing and promoting water harvesting of Gas and Nyala valleys to provide huge amounts

of water that might exceed some areas close to the Niles. They would participate into developing water sources outside the Nile areas, reducing poverty of rural communities, enhancing agro-animal production through provisioning of quality water, conserving and protecting the environment, enhancing national security and promoting peace and settlement by developing border areas and reducing water related conflicts throughout Sudan and neighboring countries, increasing per capita share of home water in line with the State's strategy in supplying quality water with sufficient quantity. They could specifically contribute into settlement of nomads to evade their conflict with peasants, and encourage refugees and internally displaced peoples to return home (DIU 2009). This is particularly significant since the areas of Gash and Nyala valleys are characterized by climatic conditions conducive to water shortage which had seriously caused many dramatic changes by disturbing the rhythms of grazing, cultivation, and migration and so compete with livestock for both land and water (Alredaisy 2012).

The Gash and Nyala are factual parts of areas of tribal and militant conflicts in Sudan. The East Front and Militant Groups in Darfur fought the Ingaz Government for decades. The initiation of tribal conflicts, prior to their politicalization, was environmentally based on shear water resources during the dry season. Implementation of water harvesting programs based on hydrological potentialities of Nyala valleys could provide reliable sources of water for rural communities and support the State's policy to achieve "Darfur's comprehensive peace" (DIU 2009). This is similarly expected by the Gash valley in Eastern Sudan, to engine targeting collecting rain water or "seizure" of flowing water during the rainy season during December- June for human and animals announced by Water Harvesting Programs of Sudan. This is important under the scenario of climate change and related anthropogenic effects in the Sahelian zone of Sudan where Kassala and Nyala areas are part of that zone. Under this climate change conditions, shortage in water production is expected, which will be more exacerbated by increasing human and animal demands. This is important to put into consideration with World Health Organization (WHO 1983) of daily allocation of per capita water, but the inclusion of animal population gives a different scene of water shortage.

Both areas witnessed onsets of desertification as it has been designated by the United Nations as under "very high risk" of desertification (UN 1977),

desert encroachment, and threat from sand creep and have been affected by changing characteristics of the rainy season since early sixties (Zeng 2003). The rainfall records of many gauge stations suggest a long-term average annual rainfall of 285 mm (1902-1990), and since the 1950s the average rainfall has fallen sharply due to severe drought from 1968 to 1972 and again in the 1980s, with 1984 being the driest year on record. The mean rainfall for 1965-84 was 214 mm, 40% lower than the 365 mm seen from 1920-39 (Walsh 1991). The decade 1981-90 was 35% below the mean of 330 mm for 1920-50. Based upon available figures there seems to be little evidence for significant improvement since 1990 (Alredaisy and Davies 2000). Rainfall figures in the 20th century suggest that the 1930s saw a peak in rainfall and that since then rainfall was generally in decline until the mid-1970s, when it appears to have leveled out at about 250 mm. These areas also face problems of global warming, rapid increase of human and animal population as manifested by deterioration of natural vegetation (Davies 1987). In such marginal lands of Kassala and Nyala, water insecure groups of the Sudan are found, who are usually poor and self-provisioning producers (Green 1989, Knerr 1998) and are pushed by land hunger into ever more marginal lands in term of weather, soil and ecological fragility (Alredaisy and Davies 2001).

The importance of water harvesting of Gash and Nyala valleys could extend to include reduction and management of urban disaster for Kassala and Nyala central-regional towns. They are both extremely vulnerable to flashy annual floods which caused damages and sometimes lead to population displacement (Alredaisy 2011). Urban disaster management and reduction strategy for both of them, the inclusion of the concept of regional flood vulnerability is a necessary prerequisite. It concerns with the capacity to resist flood of all kinds of disaster bearers at a region, and includes indicators of disaster environment, disaster drivers, disaster bearers, and disaster bearing capacity of society (GAO et al 2004). Comprehensive evaluation of urban disaster reduction management is important prerequisites for improving the level of urban disaster reduction management in Kassala and Nyala towns. Following the future strategies of world disaster reduction in 2005, it could be more effective. These strategies, which are a core task of regional sustainable development, include “construction of community disaster-reduction system, combining disaster reduction with regional development to seek the

sustainable development way and to build up safer community systems which can accept some certain risk level. It is important to establish warning systems, accelerate to share disaster reduction information and make full use of the existing disaster reduction resources in order to establish a social-economic system which can coexist with disaster risks well (Shi Pei et al. 2005).

Conclusions and recommendations

1. Geomorphological characteristics of Gash and Nyala valleys are almost identical.
2. They are of mountainous origin and although differ in geographic locations; both are influenced by the Intertropical convergence Zone (ITCZ) and Indian Ocean monsoons which initiate their annual flooding.
3. Both valleys are flashy with huge annual discharge and almost similar hydrological behavior.
4. They are source of disaster vulnerability to Kassala and Nyala regional towns and their geographic neighborhood.
5. They are proficiently potential to contribute into rural community development in semi arid Sudan in the course of appropriate water harvesting programs. This could eventually reduce vulnerability to flood disasters in their geographic neighborhoods.

The optimization of hydro-geomorphic characteristics for water harvesting and disaster management of Gash and Nyala valleys to induce rural community development, drives for recommendation of the improvement of hydrological recording and geomorphic controls on hydrology at the scale of Gash and Nyala valleys and at the scale of their physiographic regions. This is important since geomorphology exerts both direct and indirect controls on the pattern, timing and volume of runoff generated within a basin. At the scale of physiographic regions, the natural flow regime of both valleys is determined by the broad scale interaction between geology and climate which establishes the overall pattern of annual runoff, drainage network structure and the longitudinal organization of the two valleys drainage. This is important since will determine the timing and rate of runoff for individual

storm events, which are necessary for disaster management. Improvement of spatial estimates of precipitation for water harvesting and disaster management is also important. They could be computed from point measurements using well established spatial interpolation techniques. Also, estimating the spatial and temporal distribution of runoff entering the two valleys' system during a storm event is important to the understanding of the physical dynamics of catchment hydrology (Refsgaard et al. 1995). This is beside recharge estimates including physical, chemical or numerical modeling methods (Lerner et al., 1990; Scanlon et al. 2007), and flow rate estimates or water level in the channel system by using one-dimensional modeling system (Havnø et al. 1995).

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4

Food Security Intervention in Conflict Areas of North Darfur

Food Security Intervention in Conflict Areas of North Darfur⁽¹⁾

Pastoralists have interacted with sedentary farmers for millennia. Population growth and increasing commodity production have led to the expansion of agriculture on formerly shared grazing lands have increased conflicts between these groups (Fratkin,1997) in Sub-Saharan Africa (Tatlock,2006), West African sub-region; southern Ethiopia, Northern Kenya and Somalia (Mekonnen,2006). Causes of conflict include drought, economic globalization; unsustainable consumption; population growth and economic warfare (Klare, 2001). In Sudan, conflicts over resources are often escalated by high year-to-year variability in rainfall (Elagib, 2010), (Hulme, 1990), population increase and the state policies (Ayoub, 2006) and water and grazing rights (Schanche, 2007).

The current conflict in Darfur has displaced over one million who were distributed as 326,422 in South Darfur, 398,773 in North Darfur and 502,342 in West Darfur (UN, 2004). The majority (80%) were rural (Population Census, 2003) who depend solely on traditional rain-fed agriculture and animal keeping. It was estimated that 2.74 million were affected by these conflicts from whom 1.8 million were identified as internally displaced living in 125 camp, or with their relatives in secure areas. In these camps, people depend on food aid and on firewood collected from the neighborhood. It was estimated that 62% of these affected people were provided by food aid, 53% have received NFI/shelter assistance, and 36% have clean water and 18% have access to sanitation services (UN, 2004). Such interventions were done by NGOs including Sudanese Red Crescent and Save the Children/UK and United Nations agencies including World Food Program and UNICEF.

Food aid, in general, concerns with providing food and related assistance in emergency situations or to help into longer term hunger alleviation and achievement of food security (Anup, 2007). Three types of food aid could be distinguished, including program food aid, emergency food aid and project food aid which is delivered as part of a specific project related to promoting agricultural or economic development, nutrition and food security, such as food for work and school feeding programs (Anup, 2007). During much of the 1980s, work on NGOs tended to associate NGOs with the notion of more

(1) Co-authored with Hayatti, Omer A.M.

empowering, more human, and more sustainable development alternatives (Anthony, 2003). Mary (1996) views that western NGOs seek to provide emergency humanitarian relief, promote long range economic and social development in impoverished nations, promote respect for human rights and monitor human rights abuses, promote peace, often by encouraging nonviolent conflict resolution. Peter, et al. (2000) views direct activities of NGOs as to include work direct with beneficiaries and to have a direct impact on their lives while indirect activities are to affect the behavior of other actors who work with the poor or influence their lives and reach their target group through the actions and decisions of others.

However, until the 1980s, the majority of NGOs at work were international NGOs, but more recently local NGOs have become prominent force in development where in countries like India and Brazil, local NGOs now rival their international counterparts in terms of their size, impact and resources (Sarah, 2002). These NGOs intervene not only to provide food but also to supply seeds, agricultural tools and to work to conserve the environment. This is important as NGOs are less limited by political constraints and their diversity and independence allows them to work in very difficult places (Branczik, 2004) and as some argue that no discussion on poverty, equality or development today is complete without considering the role of NGOs (Sarah, 2002).

This study sought to analyze in detail food security interventions that were implemented by Intermediate Technology Development Group (ITDG) - Practical Action in rural areas of north Darfur to see how and why they were carried out, how well they were targeted and what impacts the interventions had on food security. The authors propose an integrated approach for rural development that resolve conflict in order avoid future interventions.

Setting the scene

North Darfur state is neighbored from the east by north and south Kordofan states, and from the south-by-south Darfur state, from the southwest by west Darfur state and from the northwest by Chad (Fig.1). The general physical characteristics of north Darfur are essentially the underlying rocks belong to the Basement complex. Over this lies a covering of sands (qoz) interrupted with clays (here known as gardud) with the former becoming more prominent.

The study area relies upon shallow wells for its water supply; though there are also a number of hafirs (excavated or natural hollows) where rainwater can collect and some valleys with base soil of clay and sand. Rainfall is erratic and irregular particularly in the north part and somehow higher in southern parts with a long term annual average rainfall in the order of 300 mm falling in three summer months of the year. Rainfall figures in the 20th century suggest that the 1930s saw a peak in rainfall and that since then rainfall was generally in decline until the mid-1970s, when it seems to have leveled out at about 250 mm. The United Nations desertification map distinguishes the study area within the zone having a “very high risk” of desertification (UN, 1977). Based upon figures available there seem little evidence of significant improvement since 1990 (Alredaisy and Davies, 2001). The population is a hybrid of different tribes who used to settle into small villages near water supply points and where soils are suitable for cultivation. The major crops were dukhn (bulrush millet: *Pennisetum typhoideum*) and dura (*Sorghum vulgare*), sesame, Arabic gum and groundnut. Dukhn does well on light soils. The people of Darfur used to rear livestock, including cattle, sheep, goats, and camels.

This project was launched by ITDG, Practical Action in North Darfur State. The project committed the distribution of sorghum and millet seeds; agricultural hand tools; energy saving stove; and cooking pots among targeted households living in rural areas and camps in north Darfur. These areas were held by either the Government or Sudan Liberation Army. The targeted villages were already ranked the poorest by local administrative authority between November 2002 and March 2003 and indicators of reduction or loss in crop production, lack seeds and agricultural tools were collected through Village Development Committees (VDCs) was used to determine households actually need intervention. Seeds were provided from Darfur and western parts of North Kordofan. Agricultural hand tools were manufactured locally and similarly cooking pots and improved stoves. A pre-sowing test was done to ensure seed viability before being distributed. Improved stoves component was implemented through training of groups of women in the targeted villages.

ITDG-Sudan adopts participatory approach. Beneficiaries have trained each other through village-based organizations which were already trained by the

projects' staff on how to select beneficiaries and distribute relief. Practical connections were initiated with local government partners in North Darfur State to ensure feasibility of the project. Prior to the intervention during 4-10 August 2005, various data was collected. Firstly, individual meetings were held in Khartoum with the Coordinator of Darfur Programs in Practical Action Organization. In north Darfur state, meetings were held with affiliated governmental administrations and managers of operating NGOs in Al Fashir and Kabkabyia including for example OXAM and Sudanese Red Crescent. Also, collective meetings were held, firstly with beneficiaries of the project in Abu Shouk camp to evaluate training on proper use of improved stoves, and secondly with blacksmiths in Al Fashir market to determine their benefit of manufacturing agricultural tools. A monitoring system has been applied throughout the implementation phases of the project. Evaluation of the project was carried out between 2nd and 16th August 2006 by a team of SRC. One day workshop was held with 25 participants representing villages' development committees and community base organization of Al Fashir, Dar el Salam and Korma localities, whom were entitled by their local committees and organizations. They evaluated the project using SWOT (strengthening, weaknesses, opportunities and threat) analysis.

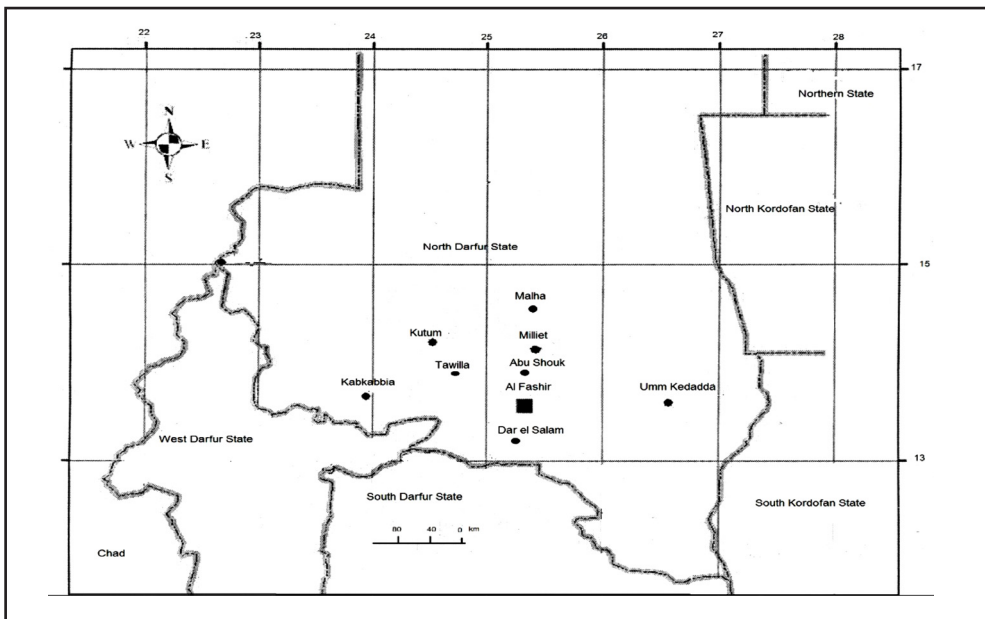


Fig.1: Location of the study area
Source: After Department of Survey, Al Fashir town

RESULTS AND DISCUSSION

The project committed the distribution of 176.7 MT of sorghum seeds and 252.42 MT of millet seeds among 25,242 household (151,450 persons), distributed as 3,750 in Tawilla; 2,500 in Tina; 2,500 in Karnoy; 2,500 in Um Buru; 12,167 in Meillet and Malha; and 1,825 in Sanam En-Naga IDPs camp (table 1). They belong to either Al Fashir or Kabkabyia localities (Fig.1). The majority of the beneficiary households concentrate in Milliet and Malha, while there were little in Sanam Ennga, and equal numbers in three locations. There was only one targeted camp for displaced people. The committed amount per household was 10 kg of millet and 7 kg of sorghum seeds to be equally among targeted households in each area (table 1).

Table 1: share of a household of sorghum and millet seeds by geographic area

location	No of households	(Amounts (metric tons			
		sorghum	percent	Millet	percent
Tawilla	3750	26.25	14.8	37.50	14.8
Tina	2500	17.50	9.9	25.00	9.9
Karnoy	2500	17.50	9.9	25.00	9.9
Umm Buru	2500	17.50	9.9	25.00	9.9
Milliet and Malha	12167	85.17	48.2	121.67	48.2
Sanam Ennaga IDPs	1825	12.78	7.3	18.25	7.3
Total	25,242	176.70	100	252.42	100

Equal amounts of sorghum and millet were distributed during 2005. In 2006, the amount of millet distributed exceeded fivefold the amount in 2005 while sorghum depicted an increase by 25% (table 2). The amount of millet eventually distributed almost equals threefold the amount of sorghum distributed. The amount of millet eventually distributed exceeds the committed amount by 22 MT while it was less by 10 MT for sorghum. Although the committed amount per household was 10 kg of millet seeds and 7 kg of sorghum seeds, it was reduced to 6 kg for millet and 3 for sorghum (table 2). This means a reduction by 40% of the committed amounts for both millet and sorghum per household depicting high demand due to run out of seed bank.

Table 2: agricultural seeds, hand tools and cooking pots distributed among targeted households

Intervention	planned 2005	Achieved			Area covered	Amount per household		
		2006	Total	%				
Agricultural seeds	Millet	MT 94	MT 40	218 MT	258 MT	274,5	Melliet - Elmalha	K\ HH 6
	sorghum	MT 54	MT 40	MT 50	90 MT	166,7	El Fashir - Kebk- abiya	K\ HH 3
Agricultural tools	Ploughs	1000	-	1390	1390	139		PI = 5-7 1 HH
	Shovels	3000	-	3012	3012	100,4	El Fashir	Sh = 1 HH 1
	Jerrayah	5000	2000	5000	7000	140	Kebkabi- ya	Je = 1 HH 1
	Pick axe	5000	2000	5000	7000	140	Melliet	Pi = 1 HH 1
	Krenkew	2000	-	-	-	0		
	Tagadi	6000	-	5500	5500	91,7		
	Najama	2000	-	1050	1050	52,5		Ta = 1 HH 1
	Hoes	3000	-	2742	2742	91,4		Na = 1 HH 1
Cooking pots	Big Pots	<u>HH 7530</u>	-	2433	2433	81,1	Melliet _ - tawilla	HH = 1
	Small pots	<u>HH 3000</u>		2433	2433	81,1		HH = 1
	Dishes			4886	4886	81,1	Dar EL Salaam	HH = 2
	Tea cups			4886	4886	81,1		HH = 2
	Water cups			4886	4886	81,1		HH = 2
	Spoons			4886	4886	81,1		HH = 2

Agricultural hand tools have included ploughs, shovels, jerrayah, pick axes, krenkew, tagadi, najama, and hoes. The majority were not distributed during 2005 (table 2). By 2006, they were considerably distributed, except Krenkew (table 2). Generally, the distributed amounts of these tools were more than what have been committed by 50% for plough, shovels, Jerrayah and pick axes, but they were less for agadi, najama and hoes, though the difference was not significant. One plough was allocated for 5–7 households due to possibility of exchange among households, while for all other tools each

household was committed by one item and although of that, there remained 500 krenkew; 950 tagadi; and 248 najama as stocking.

In addition, cooking pots, improved stoves, and kitchen utensils were distributed among targeted households (table 2). Cooking pots are durable, made of heavy mud, could retain heat and usually preferred by the community. The project committed the distribution of 25,242 sets of large and small sized cooking pots, with more emphasis towards large-sized pots. Each household will be committed by one set of both sizes as well as two pieces of kitchen utensils (table 2). The amount of cooking pots distributed was less than what committed (table 2). However, training on proper use of improved stoves started in 2005 by including 200 beneficiaries only. By 2006, beneficiaries rapidly increased to 2000 giving a total of 2200 beneficiaries. The strategy on proper use of improved stoves had focused on women training, methods of manufacturing, and awareness on their environmental impacts as reducing the consumed biomass, time spent on food cooking, and reducing health hazards related to indoor smoke.

Assessment of impact the interventions had on food security

Reports from the Village Development Committees (VDCs) and Women Development association (WDAs) were encouraging. Many groups of people came to ask about how to constitute VDC, how to access activities and to attain logistics which gave chance to disseminate innovative ideas on environmental conservation visa avis use of improved stoves and social cooperation on using some shared agricultural hand tools. The majority of the beneficiaries have agreed that targeting was essential, although few items were distributed. In their viewpoint, determination of those who really need relief intervention in such conflict areas, should depend on the most vulnerable groups to food insecurity. The targeted communities also have suggested the buildup of VDCs n all localities to assure that local communities will accept relief intervention.

SWOT analysis by stakeholders identified strengths, weaknesses, opportunities and threats as well as future recommendations for effective interventions in cases of emergency or conflict. Concerning strengths, the project has achieved its various objectives which have contributed into

improving humanitarian situation. ITDG became well known to local people in North Darfur; as it had trained small farmers on agricultural techniques; establishing seed banks; trained women groups on proper use of improved stoves that contributed into reduction of expenditure on fuel purchase, environmental conservation; and good cooperation with government officials. However, this experience also gave village development committees (VDAs) and Women Development association (WDAs) the opportunity to determine their own preferences and to facilitate practical interventions. Moreover, ITDG Darfur has had considerable success in facilitating the formation and development of (VDAs) and (WDAs), despite instability of staffing in this area. Sustainability has been the main objective of the capacity building for VDCs and WDAs; hence there was emphasis on institutional development, training in management, finance and planning as well as in technical skills and access to services. The development of VDCs and WDAs has made a significant contribution to the development of social cohesion and norms of cooperation and action for mutual benefit. The remaining funds used to fill the gap of the high demand of seeds and tools for beneficiaries. This also could be considered as a positive flexibility. As consequence, this brings the total of project beneficiaries up to 310,326 people. The planned figure for cooking sets target group was 7500 household; this figure has been reduced to 3000 household to enable families to get essential pots and other utensils. This goes in line with project positive flexibility which considered the need of the internally displace peoples (IDPs), and the general complex political emergency situation within which the project operates.

The implemented activities are generally more than what have been planned, specifically, the agricultural seeds and hand tools which might be attributed to good estimation of transport cost from El Fashir to the targeted areas. Technology programs were good at focusing on technical skills, for example to improve tools for farmers made by blacksmiths. The present project focus in El Fashir council gives an opportunity for consolidating these groups with further training, during the project extension. Furthermore, ITDGs efforts were highly appreciated for its ability to reach an increased number of communities in secure areas and similarly have maintained contact with communities difficult to access and to provide support for displaced groups.

Because the majority of NGOs working in Darfur are more interested with humanitarian relief rather than with development, ITDGs approach was

highly acknowledged by beneficiaries as it generated income to blacksmiths, improved stoves makers, and Aluminum casters as well as seed importers. The stoves component has developed a curriculum for training which was a good contribution to future efforts in energy saving and environmental conservation. In addition, the multiplier effects of the training of trainers in stoves manufacturing skills will remain impacting on people lives as far as women are training others. Although the findings of interventions by ITDG vary between CBOs and VDCs, there was evidence to sustainable food security and increased local capacities and diffusion of innovation such as improved stoves. Stakeholders have perceived that, on the long run, seeds and tools will induce self-reliance and improve household income.

Weaknesses have included slow flow of information from Community Based Organization (CBOs) and VDCs to ITDG regional office in AL Fashir town, in addition to transport and communication problems; selection of beneficiaries which required standardized targeting criteria, and need for more networking among partners. Although, VDCs and WDAs have made great progress in improving social relations among different tribal groups; they were disabling to extend such efforts beyond their immediate organizations. With the current project performance, follow up and monitoring processes for activities at CBOs and VDCs levels, this seems to be one of the project's main weaknesses. Also, there was no inherited experience from 1984/85 drought and displacement in Darfur to help into more effective work, partly due to that the majority of current operating NGOs were unfamiliar with recent situation which is more complicated. In addition, traditional coping mechanisms against drought as well as work on livestock marketing systems and stock routes, and water provisioning were not included in ITDG approach, though participatory approach was indicated.

Opportunities for the project implemented were to build upon the positive image of ITDG/Practical Action and its partners in post-conflict recovery programs; to create links with other organizations and non-Governmental organizations as well as international recognition; that could learn from each other;. Threats to the project might include desertification, delays of the rainy season, pests and diseases and military actions.

Discussion

Linking relief and development was essential part of the project. Provision of seeds was to drought and conflict affected will induce agricultural activity, ensure good harvest and secure food for households and surplus for sale. This is similar to Bujumbura in rural Burundi (Simon, et al., 2004) and Central Region of Ghana where NGO interventions on agriculture has improved the level of agriculture (Buadi, 2011). Distribution of non-food items was essential for development sustainability and environmental conservation. Such type of intervention, according to Levine and Chastre (2004), has environmental advantages and re-establishing crop production and strengthening agricultural systems in the longer term. The environmental benefit of improved stoves will reduce the biomass consumption by 40% compared to traditional stoves which consume 50% to 60% more. This is particularly true when firewood is the main source of energy for households in Darfur in which the per capita consumption is above the national average of 0.27 m³ (Forest Products Consumption Survey, 1995). Also, the project has been implemented in close collaboration with other projects such as food security, pro-poor market linkages and goats restocking that have provided an excellent opportunity to linking the project to other rehabilitation and development efforts. This agrees with cash for relief approach which includes local availability of food, proximity to markets, adequate transport infrastructure, reduces dependency on food aid, and stimulates local markets and empowers women (Robert, 2004).

The community based, or participatory approach adopted by the project has helped people to organize and depend on themselves in developing their communities. This is very important as Darfur presents an extremely difficult operating environment, according to Aranka (2001), where in-depth understanding of the context of such intervention can only be achieved through consultation and communication with stakeholders, careful assessments of the economic situation and nutritional circumstances. Furthermore, the project dependency on local blacksmiths, aluminum casters and local seeds suppliers, as requested by the community, has also contributed to building local manufacturing and suppliers' capacity and generating income. This contrasts the situation in two villages of Barisal district in Bangladesh where, although of the alleviation efforts, the majority

of the NGO beneficiaries remained below the poverty line and the underemployment line reflecting the paucities of the NGO interventions and gaps between their objectives and their achievement (Ahsan, 2007), in contrast to that NGOs were able to raise the economic status of the poor (www.helsinki.fi/university. 2008).

High yield productivity is main goal for both the Project and beneficiaries in the study area and thus priority of selecting seeds was built on best local varieties of seeds and for tools on locally made ones. This confirms the idea that, during emergencies or conflicts, interventions can be more efficiently managed by NGOs than by government (Mahmud et al 2003). The unique role of the NGOs is not confined to the delivery of social services and pro-poor advocacy. They have developed commercial ventures in order to link poor producers with input and output markets, as well as to develop a source of internally generated revenue for the organizations (Nusrat, 2008) although it was proved difficult to reach the very poorest sections of rural communities through such interventions (www.helsinki.fi/university. 2008). Analysis of the significant role played by NGOs in rural development service provisions argues that the government has to share the developmental responsibilities with NGOs, which have proved their potential in reaching the target population and that an effective partnership is meaningful for rural development in Bangladesh (Abu Elias, 2006).

The ITDG proposal for peace building was not accepted by the government due to its sensitivity as it is generally argued that political implications of NGOs work have in many cases exacerbated the very conflicts and violence they were seeking to relieve as they bring new resources into a conflict situation where each side tries to acquire and control, and so NGO aid can present a new focus for struggle (Mary, 1996). Therefore, Aid administered through government will favor those in power, while channeling aid in a way that bypasses central government can decrease a government's power, also causing problems (Branczik, 2004). However, it appears the main obstacle was the proposal to work through a particular committee, not an objection to peace building work in communities per se.

Method of analysis used to evaluate the benefits of the project might be similar to in-depth livelihoods analysis, which was to investigate the effects of the current conflict and humanitarian crisis on livelihoods of selected

communities in Darfur (Levine and Chastre, 2004) and might be also similar to the general trend that in the last 15 years of experience in Darfur, institution building is a long term process and that the early 2 to 3 years of more intensive support should be followed up.

Conclusion and recommendations

1. Food security interventions have achieved their operational objectives.
2. Participatory approach proved successful during interventions where beneficiaries, community leaders, women and village committees were highly involved
3. There was meaningful local economic stimulation through local purchase of seed and tools.
4. ITDG intervention has scaled-up the community peace building and post-war recovery activities in cooperation with other agencies in Darfur.
5. Previous experience of NGOs in geographic setting is important as proved by the previous work of ITDG in Darfur.
6. Food security interventions were not the sole solution for conflicting communities.

Though food security interventions play a crucial role into alleviation of hardships, but there should be a way forward to overcome conflict. This is particularly needed as “humanitarian aid and development assistance are not straightforward, and they mask many political failures” (Branczik, 2004). The conflict in Darfur is particularly vital for a conflict riddled country like Sudan where resource-based conflicts have imperatively affected rural societies. Some scholars have proposed solutions for natural resources-based conflicts. One example is that by Mekonnen (2006) who recommended the building of an early warning system that should be adopted at local, national, and regional levels for mitigating impacts of drought, famine and conflict. Here, the authors argue that human, environment and resource utilization should be interrelated to resolve conflicts. Community based knowledge is essential as it included social norms and cultures which respect others’ rights into use of resources. This will contribute to building relationship

among and across communities which diminishes the frequency and intensity of conflict, and encourages cooperative solutions to other problems. Building capacity of the institutions of the nomads including traditional administrative systems; culture of raising animals; and use of water points; mobility in search for pasture and knowledge sharing will make these communities more aware on misuse of resource utilizations and their impacts. Addressing specific needs of local populations, enhancing local knowledge and skills, building the capacity and preparation of traditional mechanisms for combating drought are essential such as collecting/harvesting rainwater in man-made ponds, diversifying grazing lands, and planting trees.

Rehabilitation of degraded rangelands, reserve of green belts, rainfall database, and permanent water points are major axes for the environment sustainability. Rehabilitation of degraded rangeland will keep on recent use and increases its future holding capacity. Research on drought and desertification is essential where the role of official authorities is remarkable either by monitoring or aware of people. Reserves of green belts will aware people to respect natural resources in order to respect others' rights on resources. Rainfall database will provide information for the agricultural season, expected pasture, locations for good agricultural production and vulnerable areas to crop failure and expected food shortage in order to avoid excess use by farmers or herders. Permanent water points have to be in accordance with rainfall database and population density taking physical characteristics of an area into consideration. Resource Utilization should include mobile extension team, community resource management bodies, secondary data for cattle routes and pastoralists movements, participatory demarcation with concrete posts for livestock routes and conflict prevention, mapping of long livestock routes. In addition, maps and secondary data for cattle routes and pastoralists movement should be introduced with local patrolling team comprising representatives of pastoralists, farmers, native administration and the old system of pastoralists. Introduction of small credit finance system, agricultural co-operative societies. Empowering farmers and pastoralists institutions to strengthen their capacity to understand tenure rights, knowledge sharing on natural resources management are also essential.

Managing relationship between man, the environment and resource utilization are important as civil wars in southern, western and eastern Sudan are

ignited by issues of marginalization, lack of development and infrastructure. However, understanding how communities access natural resources and tensions and rivalries entailed in this process is critical not only for discerning livelihood systems, but can also inform sustainable development policy in Sudan.

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5

Health hazards relating to drinking water in Kas town, southern Darfur

Health hazards relating to drinking water in Kas town, southern Darfur⁽²⁾

Much of the diseases in the developing countries have to do with the fact that most people do not have access to safe drinking water. In Africa, there were 300 million people did not have access to safe drinking water during 1981-1991 (Nyrumby, 1986), and this figure more than doubled during 2001-2010 (WHO, 2009). Based on NASA and World Health Organization, severe water shortage will affect 4 billion people by 2050.

Human beings need to be safe from harm (Maslow, 1968) and the Universal Declaration of Human Rights (1948) implicitly recognized that (Twigg, 2001). The need to determine drinking water quality for safe human consumption has been well recognized since 1855 when outbreaks of typhoid fever and cholera were related to water contaminated with faecal wastes (Moore, 1974). The World Health Organization (1985) defines access to safe drinking water as provision of piped water to housing units or to public standpipes within 200 m of each household. It stipulated 40-50 liters per day per person is adequate (WHO, 1983) Where water quality can be detected by the presence or absence of pathogenic organism. The presence of faecal material in waters presents the most immediate hazard to Health and if water contains more than 10 coliform 1 Escherichia Coli per 100 ml of water it will be considered contaminated and unsuitable for human consumption (WHO, 1983).

Chemical assessment of drinking water is also important from the viewpoint of public health. It includes detection of heat (temperature), alkalinity, acidity, chlorine, calcium, Sulphur, ferrous and electro-conductivity. The World Health Organization (1984) did not recommend guideline value for water temperature since its control is usually impracticable. However. low water temperature would tend to decrease the efficiency of treatment processes including disinfection and may thus have a deleterious effect on drinking water quality and growth of microorganisms. For drinking water to be germ-free, it has to be disinfected by chlorine compounds, including chlorine gas, sodium hypochlorite, calcium hypochlorite and ferric chloride (FeCl_3) are widely used. The recommended level of chlorine for drinking water is 250 mg/L (WHO, 1984), and it is widely used as a water disinfectant for community water supplies because of its comparatively low cost and ease of application.

(2) Co-authored with EL-Bushra, Sayyed M.

Calcium recommended concentration in drinking water is 75-200 mg/L, while for ferrous it is 0.3 mg/L. Electro-Conductivity (EC) of ions indicates the ratio of total dissolved salts and reversely an increase in electro-conductivity means an increase in water salinity. The standard EC unit used by the Victorian Salinity Program and the Murray Darling Basin Commission is micro-Siemens per centimeter ($\mu\text{S}/\text{cm}$) at 25°C where EC range ($\mu\text{S}/\text{cm}$) 0 – 800 $\mu\text{S}/\text{cm}$ is good drinking water for humans (provided there is no organic pollution and not too much suspended clay material). The EC range ($\mu\text{S}/\text{cm}$) 800 - 2,500 can be consumed by humans although most would prefer water in the lower half of this range. The EC range ($\mu\text{S}/\text{cm}$) 2,500 - 10,000 is not recommended for human consumption, although water up to 3000 $\mu\text{S}/\text{cm}$ could be drunk if nothing else was available.

Water alkalinity is useful since it acts as a buffer against changes in pH where its international standard is recommended in the range 6.5 – 8.5 (WHO, 1971). The alkalinity of water may be defined as its capacity to neutralize acid. Alkali substances in water include hydroxides or bases. They can be detected by their acid taste. Moderate concentrations of alkalinity are desirable in most water supplies to balance the corrosive effects of acidity. Strongly alkaline Waters have an objectionable “soda” taste. The EPA Secondary Drinking Water Regulations limit alkalinity only in terms of total dissolved solids (500 ppm) and to some extent by the limitation on ph.

Phosphates and silicates are rarely found in natural supplies in concentrations significant in the home. Compounds containing these ions may be used in a variety of water treatment processes. However, excessive quantities cause a number of problems. These ions are free in the water, but have their counterpart in cations such as calcium, magnesium and sodium or potassium.

The Pressure and Release Model can reduce the impact of a hazard (Blaikie et al, 1994, Wisner et al, 2004). This model has become internationally accepted for explaining progression of vulnerability (risk accumulation) and progression to safety (risk reduction). The model emphasizes locally based action to reduce occurrence, frequency or strength of hazards. Also, it identifies elements to withstand the impacts of hazards and safe conditions by all vulnerable people who have capacities to be nurtured and used to lessen the impacts of hazards. Also, it releases pressures that some processes and structures such as community-based organizations may actually work to

lessen vulnerability. This paper adopts this model in an attempt to reduce health hazards relating to drinking water in Kas town (figure 4).

Kas town water

Field observations and direct interviewing with local people, resident water engineers at Kas water stations and UNICEF water engineers and officers during 2008, and also data provided by Hunting Company on chemical analysis of underground water revealed high levels of chloride, alkalinity, salinity, calcium, ferrous elements and electro-conductivity into 23 wells (table 2). Calculations of the mean and the standard deviation were done for water chemical data.

Kas town is classified as small town according to its population size of 103556 persons (Sudan Census, 2010). It lies between 12 30" N and 24 17" E. and bordered by Jebel Merra, Nyala, Idd el Firsan, Wadi Salih and Zalingi localities from the north, east, south, west and northwest respectively (Figure 1). Basement complex and metamorphic rocks form the underlying structure of Kas town (GRAS. 2005). Sedimentary rocks are the superficial deposits (Whiteman, 1971) as well as the prevalence of sand dunes over the surface of Darfur (Parry et al, 1981).

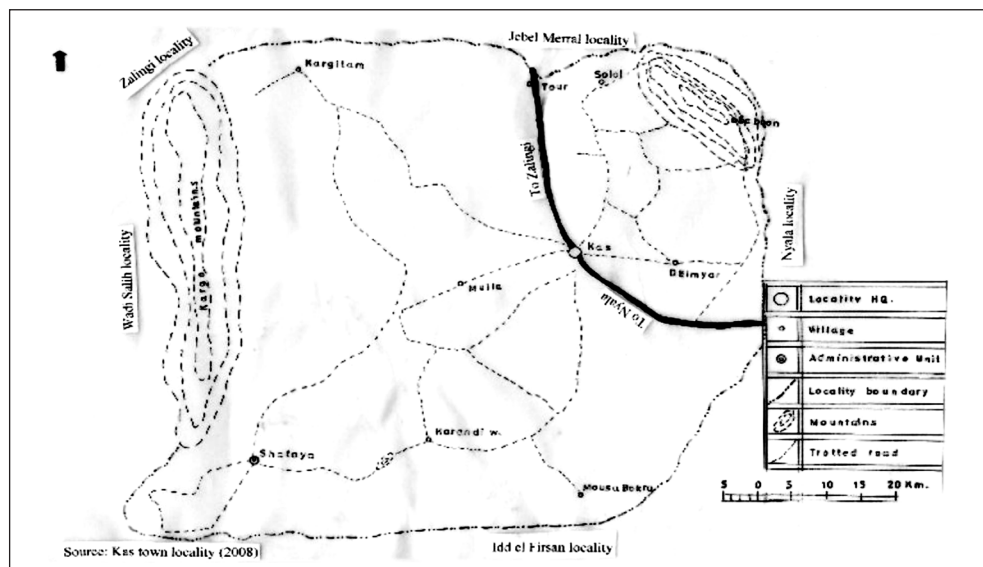


Figure 1: Kas Town
Source: Author's own work

The climate is hot and dry during most of the year with a mean temperature of 28 °C during winter (November-January). Soil types include sandy, sandy clayey and clayey soils. Vegetation cover includes Acacia trees and rich savannah grasses.

Tribes of Kas town are Zaghawa, Fur, Tungur, Brti, and Masaliet Hausa, Rizaigat, Bani Halba, and Chadian migrating tribes, being under official and traditional administrative systems. People practice cultivation, animal keeping, trade and traditional industries. Rain-fed agriculture is near water valleys, mountainous areas and sandy/clayey plain in neighborhood. People cultivate sorghum, bulbrush millet, ground nuts, broad beans, sesame and water melon during the rainy season, and vegetables and citrus during winter. People keep animals within their neighborhoods where their number amounts to 154,500 head (Veterinary Office, 2008). They move during the rainy season and stay around during winter season depending on fodder, farming remnants. Traders are mostly involved into agro-animal products and similarly traditional industries producing shoes, bags, straw mats, cheese, etc.

Water production, distribution and consumption

The estimated amount of underground water in Kas town is 35 million m³, distributed mostly within two major aquifers composed of gravel and sand (Hunting Company, 2008). Kas's aquifers holding capacity is 8 million m³ with mean thickness of 20 meter. Gumaiza aquifer holding capacity is 3 million m³ with mean thickness of 15 meter (figure 2). Both aquifers have general permeability of 5-7 meter/hour. The highest level of underground water is recorded at the confluence of Gandati and Garah valleys where there are 23 wells dug there. They are the two main charging sources of water for these two aquifers, being enhanced by rainfalls which start in May up to mid of October, with annual average of 500-900 mm, a peak in August and annual fluctuation by 25% (Meteorological Office, Kass, 2008).

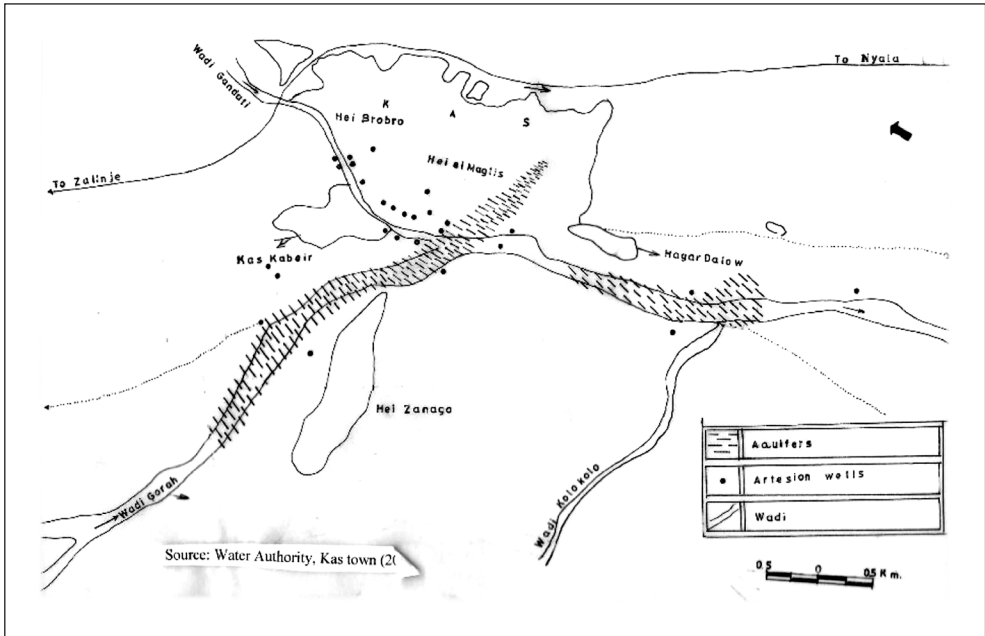


Figure 2: Aquifers in Kas town
 Source: Author's own work

The fieldwork revealed that there are only 8 operating wells out of 23, and the average water production by a well per hour is 10 m³, while average hourly pumping is 10 hours per a pump (Kas Waters Authority, 2008). Based on that, total of daily production is calculated as follows: -

No. of wells	No. of operating wells	Daily production
23	8	m ³ 800

Note: 1M3 = 1000 liters

The Jordanian Voluntary Authority established water network of Kas town in 1988 serving the town in situ. The town grew and the population more than tripled (Population Office, Kas town, 2008). According to the fieldwork results, the majority of town's population depends on water vendors while few have adequate piped water. The UNICEF provided and managing 58 water pumps in densely populated parts of the town with 250 persons holding capacity per a pump (Kas Waters Authority, 2008). Interviewing with water resident engineers in Kas town revealed that breaks, cross connections and pipe walls halted network full capacity for water distribution.

Kas Waters Authority (2008) estimates 500 m³ total daily consumption of water by the population. However, the fieldwork estimated 2000 m³ daily consumption, based on 20 liters (0.02 m³) for a person and population size of 103556 persons. The difference is threefold between the two estimations. Fetching for daily water takes 2 hours, a duty done by women and young children. The pricing of water is 100 SDG per tin (equals 4 USA gallons = 16 liters). This makes the average family of 6 persons (fieldwork, 2008) pays 22 SDG/ month compared with 15 SDG a family pays in Greater Khartoum, an excess by 33%.

Animals estimated daily water consumption is 2750 m³ (table 1), exceeding human consumption by 750 m³. But, animals staying away for some months of the year makes water surplus for people. Estimated daily water requirements for both human and animals consumption is 4750 m³, apparently exceeding production.

Table (1): Animal daily, monthly and annually water consumption in Kas town (liters)

Animal type	number	Daily/ head	Total daily
1- Camel	12500	36	
2- Cows	25750	10	450,000
3- Goats	56500	10	515,000
4- Sheep	44250	18	565,000
5- Horse and donkeys	15500	94	442,500
6-Total	154,500		2,751,000

Note: calculations are based on data provided by Population Office, Veterinary office and Water Authority in Kas town (2008).

Chemical properties of drinking water

Chemical properties of drinking water are important enough to determine water suitability for human and animal consumption. Here, some results are available for Kas town (table2).

For water temperature, underground water is generally clean and somehow cold compared with surface water because when such water pass through strata lose oxygen so as to dissolve organic matter and holds elements

affordable for solution in water like ferrous and lose bacteria. Average concentration of calcium in drinking water of Kass town is 68.4 mg/L which is less than the lowest recommended limit of 75-200 mg/L. The value of the standard deviation as 6.4 mg/L indicating to wide differences on the levels of calcium concentration in water wells within the town as the range is 7-240 mg/L. Alkalinity ranges between 42 and 683 with small standard deviation value of 7.0 and mean value of 161.5 while the worldly recommended level is 6.5 – 8.5 mg/L which means highly exceeding the safe level.

The mean of Chlorine values is 64.73 mg/L which is less than the World recommended level of 250 mg/L, with standard deviation value of 2.8 indicating to high discrepancy within the water wells of the town. Sulphur level is recorded within three wells only giving a mean value of 16.3. Ferrous mean value is 0.37 and almost equals the Worldly recommended level of 0.3 mg/L with standard deviation value of 0 .02 indicating to closer values within the wells. However, the mean value for electro-conductivity (EC) is 531.9 ($\mu\text{S}/\text{cm}$) and the standard deviation is 23.12 indicating to uneven distribution within the wells and by so to the ratio of total dissolved salts which reversely increase with increasing electro-conductivity and consequently determining water salinity. EC range ($\mu\text{S}/\text{cm}$) 0 – 800 $\mu\text{S}/\text{cm}$ is good drinking water for humans, provided there is no organic pollution and not too much suspended clay material.

Table (2): Chemical properties of drinking water in Kas town (1mg/liter)

Well .No	Calcium	alkalinity	chloride	sulphur	Ferrous iron	Electro-conductivity ($\mu\text{S}/\text{cm}$)
1	169	73	38	19	0.1	140
3	19	42	16	13	0.8	75
5	20	94.5	11	17	0.3	240
7	7	47	23	-	0.7	78
8	240	530	500	-	-	1000
9	198	361	253	-	-	710
10	58	81	28	-	0.1	120
11	31	683	13	-	0.7	1200
12	39	155	59	-	0.2	200

14	35	85	38	-	0.1	200
15	62	263	62	-	0.5	490
20	166	208	41	-	0.3	480
23	70	1116	42	-	0.9	390
24	127	184	61	-	-	360
25	23	86	39	-	0.2	200
26	41	69	28	-	0.3	200
28	73	57	67	-	0.3	200
31	38	76	30	-	0.3	105
30	33	49	28	-	0.9	110
35	31	47	23	-	0.4	120
36	23	253	28	-	0.3	160
41	27	92	36	-	0.1	140
43	43	63	23	-	0.2	15
23=∑ wells	X=1573∑ x̄ = 68.4 Std= 6.4	X=3715∑ x̄= 161.52 Std= 7.0	X=1489∑ x̄= 64.7 Std= 2.8	X=49∑ x̄= 16.3 Std= 5.4	X=0.77∑ x̄= 0.37 Std= .02	X=12235∑ x̄= 531.9 Std= 23.12

Source: Hunting Company,2008

Vulnerability to health hazards relating to drinking water

This subject could be discussed within water shortage, water maldistribution and water chemical properties which are diagrammed in figure (3).

Health hazards relating to water shortage

Inadequate water supply, or water shortage, in Kas town subjects the population to water shortage diseases. The daily consumption of an individual of water of 20 liters is far below than the recommended level by WHO (1983) for an individual to remain healthy, as it stipulated 40-50 liters (0.04 - 0.05 m³) per day per person is adequate. Water shortage causes infectious diseases as for example; trachoma, skin infections, intestinal infections, diarrhea; eye infections as well as personal unhygienic, food insanitation. Studies in USA and Sudan suggest ½ to ¾ bacilli dysentery being related to water shortage (Ciba, 1974).

Water washed diseases are caused by water scarcity where people cannot wash themselves, their clothes or home regularly. Trachoma for example, is the main cause of preventable blindness in the developing world, with four million sufferers, an estimated 500 million at risk and six million permanently blinded. It is common in areas that are hot, dry and dusty, such as Kas town. Trachoma is spread, especially among young children, by flies, fingers and clothing coming into contact with infected eyes, spreading the infection to other people's eyes. The infection causes a sticky eye discharge with soreness and swelling of the eyelids. After repeated infections scarring of the inner eyelids occurs which can lead to trichiasis where the eyelashes turn inwards. These then rub on the eye, scarring the cornea and causing blindness.

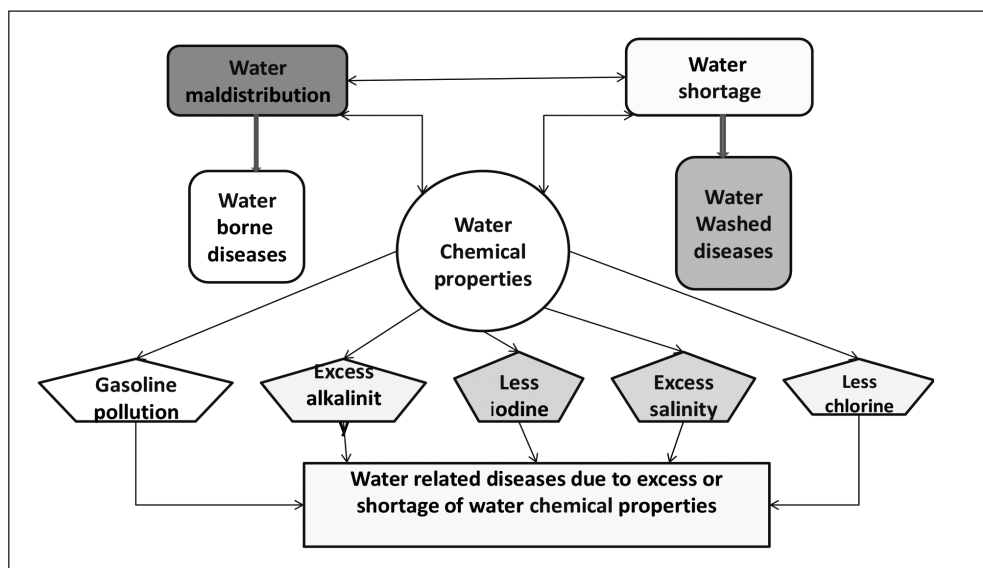


Figure (3): Water health hazard and related diseases in Kas town
 Source: Fieldwork, 2008

Scabies occurs in areas where there is a lack of water and people are unable to wash themselves, their clothes, bedclothes or houses regularly. It is caused by the scabies mite which infests the surface layer of the skin. The mite can spread from one person to another through personal contact. Scabies causes itchy sores and lesions mainly between the fingers, wrists, elbows, breasts and pubic areas. In younger sufferers more areas, including baby's feet and the head, can be infected. Because sufferers often scratch the sores and lesions, they become prone to other infections.

Vulnerability relating to water maldistribution

Water borne diseases are caused by viruses, bacteria, helminths, unicellular, leptospiral, Cyclopes and snail, which cause hepatitis, typhoid, gastroenteritis, giardias, dysentery, etc diseases, are associated with misdistribution of drinking water. Water-borne diseases are any illness caused by drinking water contaminated by human or animal faeces, which contain pathogenic microorganisms and are directly transmitted. Contaminated fresh water, used in the preparation of food, can be the source of food borne disease through consumption of the same microorganisms.

Because water distribution in Kas town is mostly depending on vendors as the fieldwork results revealed, studies worldwide linked between health hazards and vendors. The study of Alredaisy (1993) shows that, the presence of *Escherichia Coli*. by 14/100 ml, in Mayo area, in the Green Belt area of southern Khartoum, exceeds the limit of 10/100 ml documented by W.H.O (1983). This is because the main water pipe at the borehole is in close contact with earth contaminated by animal faeces. This is in addition to the lack of vendors' personal hygiene and the use of filthy barrels. According to the World Health Organization (2009), diarrheal disease accounts for an estimated 4.1% of the total daily global burden of disease and is responsible for the deaths of 1.8 million people every year. It was estimated that 88% of that burden is attributable to unsafe water supply, sanitation and hygiene, and is mostly concentrated in children in developing countries. The Annual Health Statistics Report, indicated to the prevalence of typhoid, dysentery, gastro and diarrhoea in southern Darfur, including the study area (Ministry of Health, 2008).

Resident water engineers in Kas town (fieldwork, 2008) show that, due to breaks and cross connections and pipe walls, it is expected that physical and hydraulic integrity can lead to the influx of contaminants across them. These external contamination events can act as a source of inoculums, introduce nutrients and sediments, or decrease disinfectant concentrations within the distribution system, resulting in a degradation of water quality. Even in the absence of external contamination, however, there are situations where water quality is degraded due to transformations that take place within piping, tanks, and premise plumbing. Decreases in disinfectant concentrations with travel time through the distribution system could be the result of demand

from an external contamination event or it could be due to disinfectant reactions with pipe walls and natural organic matter remaining after treatment. They further indicated that specific reactions occur that introduce undesirable compounds or microbes into the distribution system. These reactions can occur either at the solid–liquid interface of the pipe wall or in solution. Obvious microbial examples include the growth of biofilms and detachment of these bacteria within distribution system pipes and the proliferation of nitrifying organisms. Important chemical reactions include the leaching of toxic compounds from pipe materials, internal corrosion, scale formation and dissolution, and the decay of disinfectant residual that occurs over time as water moves through the distribution system.

Vulnerability relating to chemical properties of water

In the absence of exact scientific information, scientists predict the likely adverse effects of chemicals in drinking water using human data from clinical reports and epidemiological studies, and laboratory animal studies (Sandra et al, 1996). Excess or deficit in a chemical property of water in Kass town indicated to vulnerability to some health hazards associated with each one. The results of this paperwork suggested that water temperature is normal, and for the safe levels recommended by World Health Organization, chlorine and calcium records are less than the recommended levels, while alkalinity highly exceeds the safe level, water salinity is good, provided there is no organic pollution and not too much suspended clay material.

Studies worldwide have closely referred many health hazards to inappropriate chemical properties of drinking water. Since underground water is generally cold if compared to surface water it is expected by so to influence taste since warm water tastes flat and inspired partly as a result of the decreased solubility of oxygen and carbon dioxide at elevated temperature. Cold water is generally more palatable. However, low temperature would tend to decrease the efficiency of treatment processes including disinfection and may thus have a deleterious effect on drinking water quality. Microorganism's growth in water is influenced by temperature like in any other environment.

Excess chloride causes undesired teeth colors, while less chloride subject drinking water to infection by microorganisms. Therefore, chlorine is widely

used as a disinfectant. Calcium affects blood channels and kidney and lead to hypertension, rickets, kidney diseases and cadmium Hardness is due to calcium and magnesium dissolved in water. Highly mineralized alkaline waters cause excessive drying of the skin due to the fact that they tend to remove normal skin oils. Ferrrous iron level in Kas town imparts a bad metallic taste. It causes rust stains in toilets, plumbing fixtures, tableware and laundry. As little as 0.1 ppm of iron can cause these problems. Iron can exist in water in one of two forms or both. Treatment depends on the form of iron present. Waters containing “ferrous iron” are clear and colorless when drawn. Exposure to air converts ferrous iron into the insoluble, reddish brown “ferric iron”. Iron can also contribute to hardness. These elements form scale in piping, water heaters, and dishwashers causing expensive repairs. Ferrrous oxides cause abdominal, clumsiness convulsion, extensor and brain damage and influences neuron cells and accumulate in bones and active in blood, liver, Pancreas and kidney Sulphur oxides affect lining of respiratory tract (Meade et al, 1988).

Water salinity level is good in Kas town but, biological contamination and suspended clayey material discard its value. Scientists report that over 150 degenerative diseases are caused by high acid levels in the body. The pH scale ranges from 0 to 14, with 0 being extremely acidic, 14 being extremely alkaline and 7 being neutral. Body fluids range between 4.5 and 7.5 pH (blood must maintain 7.35 to 7.45 pH). A one-point drop on the pH scale is 10 times more acidic. In order for the body to remain healthy, it keeps a delicate and precise balance of blood pH at 7.365, which is slightly alkaline. High systemic acid levels contribute or cause directly, numerous health problems. Acid systems can't use calcium effectively. They can't maintain proper blood oxygen levels and cancer can only develop in an oxygen poor, acidic environment. Acidic blood can't circulate properly creating extra strain on the heart. It adversely affects the digestive system and the lymphatic system.

Gama' (1999) indicated to shortage of Iodine in drinking water in Kas town which causes goiter gland diseases. Prevalence of Iodine disorders among school children of Delhi showed that IDD continues to be prevalent in mild endemic proportions. Compared to the results of previous surveys, the IDD rate has declined in the last few years. However, it continues to be an important public health problem in Delhi (Pandav et al, 1997). A preliminary

investigation of the Iodine content of salt on sale in Western Kenya is that Iodine deficiency disorders are known to be a potential problem for large numbers of people living in the highland areas of Western (International Council for the Control of Iodine Deficiency Disorders, Articles.mht). The fieldwork also detected contact of gasoline used for pumping with water as pumps were positioned directly over well cover which subject water to water-based diseases.

Conclusion

Aquifer depletion is a new world problem. Water tables are falling in large portions of continents from over-pumping of groundwater. Kas town is not exceptional; its population is vulnerable to health hazards associated with water shortage, maldistribution and chemical properties. High rates of population growth and subsequent increasing demand, low priority given to water treatment together with climate variability and droughts increased the pressure on water resources in this town and may lead to conflicts over water.

Based on Pressure and Release Model, developing water resource capacity in Kas town can reduce vulnerability to water related diseases through community involvement, introduction of education hygienic education by enhancing community groups of women and youth, rainwater harvesting, reducing number of animals and construction of rain water reservoirs (figure 4).

The control of waterborne diseases requires a safe water source of a high quality and with enough water for the practice of general water hygiene, which will ensure that the water stays safe. Also, the control of water-washed diseases depends on easy access to large quantities of water and the motivation to use more water for personal hygiene, whereas the quality of the water used is less important. Similarly, the control of water-based diseases depends on elimination of contact with the infected water source. The availability of water is essential for water hygiene and naturally, an easily accessible water source facilitates the practice. But to ensure that water hygiene is practiced daily, the water source must be reliable both in quantity and quality throughout the year. An improved water source can be contaminated if poorly maintained.

The motivation of the community to maintain and protect their water source is, therefore, of critical importance to ensure a sustainable reduction. Strengthening rain water harvesting networks, when there are 500- 900 mm annually rainfall, will facilitate the promotion of knowledge and build data base of practice and endeavors to disseminate such understanding. Water harvesting can be done by households and official authority. Provisioning of small water tanks, using houses' roofs and huge trees storage will provide drinking water during the rainy season and a reserve for the rest of the year. Official authority can gather water draining by small valleys to enhance underground water chemical properties for better and reliable consumption.

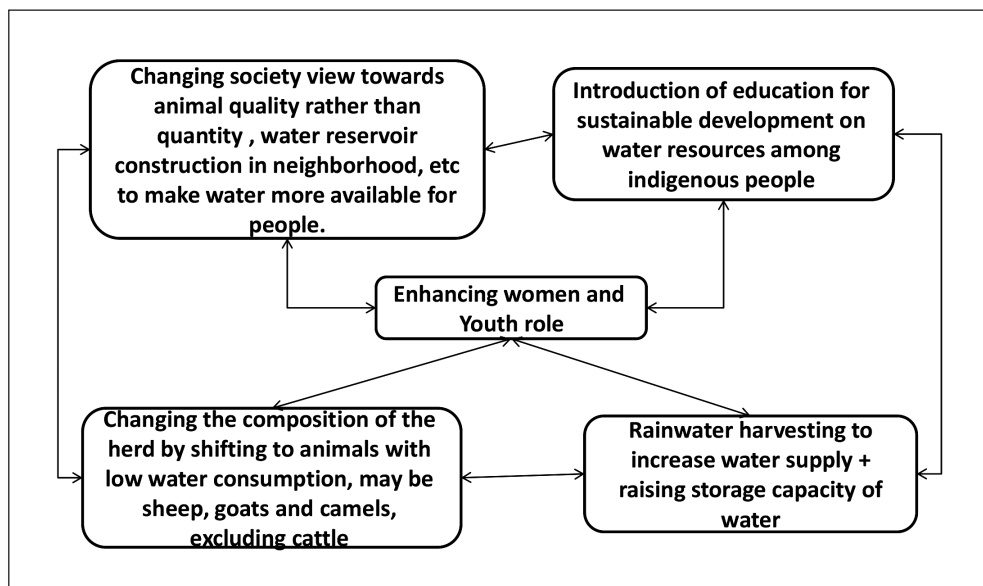


Figure (4): Developing water consumption capacity to reduce diseases related to water quality and quantity in Ksa, southern Darfur, Sudan

Introduction of education for sustainable development (ESD) into schools' curricula, students' activities, mass media and youth clubs will inform the community on rational water use. Sustainability at any level requires the involvement of local level communities. Involving men and women for sustainability will ensure sustained use of the water resources in Kas town. Women are important target group, as they play a significant role in rural family life and have a prominent role in improving the hygiene within the family. Planning and implementation of hygiene education is essential to

ensure community participation. Hygiene education should aim to actively involve the entire community.

Through increased knowledge and awareness, the community can be motivated to take better care of their water source and practice better water hygiene when collecting and storing water, use more water for hygienic purposes. School teachers should be trained to promote hygiene education, particularly in primary schools. Further to reinforce the practice of better hygienic behaviors, all schools should have, and encourage the use of hygienic latrines with hand-washing facilities close by. Drinking water should be safely stored and refuse properly disposed. Finally, hygiene education should also be an integrated part of the training of all personnel involved in the water and sanitation program; the extension worker, the drilling crew, the pump mechanic, the caretaker and the driver. They all have a unique chance to teach hygiene education when in the communities.

Changing the composition of the herd by shifting to animals with low water consumption, may be sheep, goats, and camels, excluding cattle and changing the society view towards animal quality rather than quantity will relieve pressure on water resources and provide additional water for people. This can be enhanced by construction and maintenance of rainwater reservoirs in the town's neighborhood. The follow up of this proposed model is integral part of the strategy for reducing health hazards relating to drinking water in Kas town. But above all, working towards social and political stability of Darfur will benefit formulating national water strategies in Sudan. Those strategies have to consider maximizing rational use of water resources in situations of changing societies and global warming

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6

Mesquite 'Prosopis spp.'
expansion in Toker Delta,
Red Sea Coast of Sudan



Mesquite 'Prosopis spp.' expansion in Toker Delta, Red Sea Coast of Sudan

Mesquite which means “towards abundance” is a weed of world significance due to its invasiveness and subsequent ecological, economic and social impacts (Robinson, 2008). The common species of mesquite include Honey Mesquite (*Prosopis glandulosa*), Screwbean Mesquite (*Prosopis pubescens*) and Velvet Mesquite (*Prosopis velutina*). Although Botanists do not agree on the exact classification of these three mesquite species, but no one disputes the success of their adaptation to the desert environment (Desertusa.com.2011). They are thorny leguminous shrubs or trees belong to the leguminosae family. Mesquite ranges from 1-meter-tall shrubs to 18 meters tall trees (Asim, 2007).

Mesquite is a successful invasive plant due to its ability to reproduce large numbers of easily-dispersed seeds, and vegetative growth by suckering to create thick monotypic stands that shade out all competing plants nearby and requires less than four inches of annual rainfall to establish itself and survive (Madhoolika, 2011). It survives well in dry environments due to its extremely long taproot, withdrawing moisture from soil, grows in sandy, dry, degraded slopes and salty soils and rocky cliffs where other plants do not grow. The mesquite's roots are considered the longest of any desert plant (The Maui Plant Chronicles. 2011) and have been recorded as long as 50 meters (Asim, 2007) and 80 feet (Desertusa.com 2011, ebow.com.2011) or even 200 feet (World Environment Library. 2011), as well as subsurface root system to capture moisture from even the smallest rainfalls (Angelo.edu.2011). Plentiful underground water supply enables mesquite tree to reach over 40 feet in height and 3 or 4 feet in diameter (World Environment Library. 2011). Because mesquite is a salt tolerant and phreatophytic N₂-fixing tree legume (Burkhard and Simpson, 1977), It dominates arid and semi-arid regions where soluble soil salts (alkali) excessively accumulate in lowlands and hinder water absorption, delay seed germination and affect soil structure (soilandhealth.com 2011). Mesquite enhances its physiological processes related to proper energy utilization by making benefit from the available Phosphorus which is naturally occurring in the environment or can be added to the environment by man's activities (Mike, et al., 2011). Mesquite is also tolerant to acid soil solution although it may affect plant growth,

prevents normal decay of humus and promoting the accumulation of resulting toxic organic substances, limiting potassium availability and other soil salts (Soilandhealth, 2011). In addition, mesquite adapts with varying soil temperature which has an effect on seed germination, bacterial and chemical activities in the soil and functions of roots and the vegetative development of plants (Soilandhealth, 2011). In addition, mesquite adapts with climatic fluctuations which influence vegetation dynamics in desert and semiarid areas (Godfrey, et al., 2008). Mesquite spreads via ruminants which ingest seeds and excrete them in manure. With a high content of hard seed, passage through the digestive system of ruminants acts to scarify mesquite seed.

In many arid and semiarid ecosystems, mesquite has increased abundantly displacing native grasses (Biggs, et al., 2002). Mesquite is invading India, Pakistan, South Africa, Egypt, Kuwait, Australia, U.S.A. (Hawaii), and Brazil, (Kay, et al., 2007), southern Arizona (Arizona Board of Regents. 2009), Western Australia (Robinson, 2008), semi-arid regions of northern Mexico and the southwestern USA (Brunel,2009), upper San Pedro River watershed, which extends from northern Sonora (Mexico) to southeastern Arizona (Brunel,2009), covers almost one million hectares of Australian land with the potential to cover 70% of mainland Australia (EKSA,2010), the Rusizi floodplain and delta (IUCN.2010), Baringo District of the Rift Valley, Kenya (Okello,2008). In Kassala State, eastern Sudan, mesquite invaded valuable agricultural lands and sometimes grows into impenetrable thickets causing enormous problems to farmers and agricultural managers (Abdelmagid, 2008). Similarly, in New Wadi Halfa scheme in eastern Sudan, mesquite spread had created on-farm problems in spite of the various benefits provided (Mai, 2008). Research Institute on Humanity and Nature, 2007, has detailed the human and ecological factors affecting mesquite growth in several distinct environmental contexts of the Red Sea coast (Research Institute on Humanity and Nature, 2007), including Delta Toker.

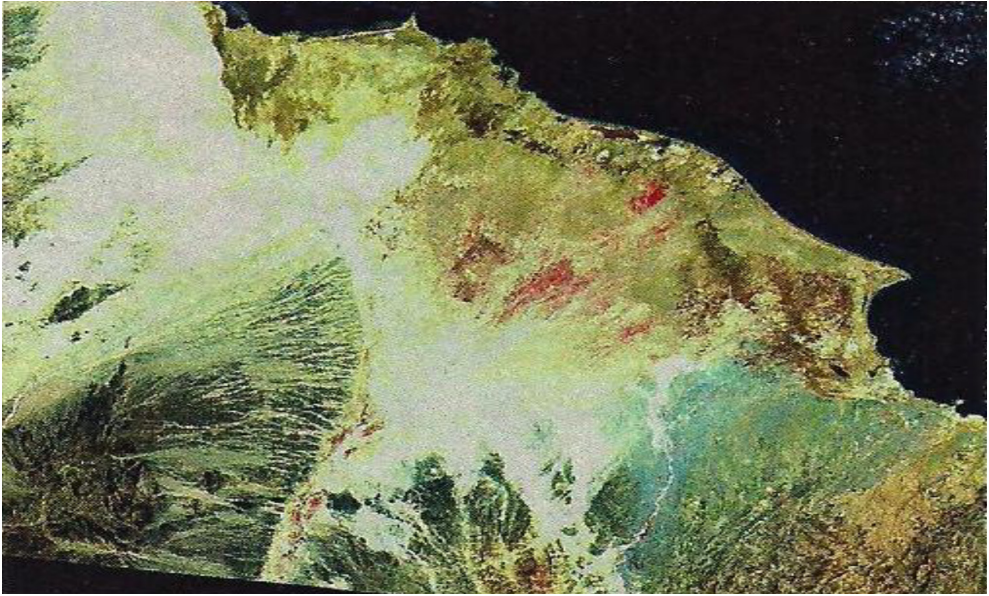
Although of these threatens, mesquite as leguminous plant increases soil fertility, need irrigation once or twice when firstly planted, grow rapidly, do not invade rainfed irrigated areas with heavy dry clayey soil and also incapable to spread into sandy soil areas. It was found that mesquite has a positive effect on the arid and semi-arid ecosystems as they increased soil organic matter and soil N content (Herrera – Arreola, et al., 2007). In Mexico, mesquite

is the main source for feeding livestock and wild animals. In Yemen, every km of mesquite belt gives 10 to 25 cubic meters of wood income per year and provides fodder for fifty head of sheep and goats (Bazraa, 1983). There are a few species of tree that survive the nutrient-poor sandy soils of a coastal desert where mesquite is a classic skeleton of a tree that is used for its wood (ehow, 2011).

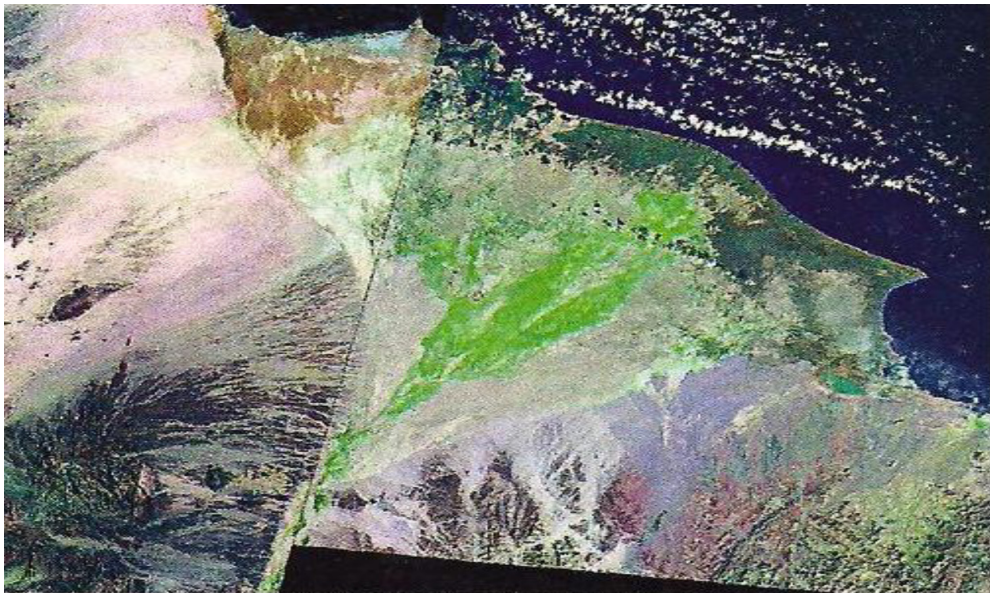
This paper objects to identify space-time aspects of mesquite expansion, specifying vulnerable areas and link physical properties of the Delta with mesquite expansion in order to build a model for its control. The paper firstly considers physical properties of the Delta to be linked later with mesquite expansion which was firstly outlined.

Data and Methods

Landsat MSS 1976 (Fig.2 A); TM 1986 (Fig.2 B) and ETM 2000 (Fig.2 C) which were provided by ACSAD (2005), depict mesquite reflectivity into heavy and light green. ERDAS 8.4 version identified mesquite reflectivity into light green. Non-supervised classification of satellite images was applied. Convert to Polygon Technique of Arc Map 9.3, was used to divide satellite images into polygons to enable area measurement occupied by mesquites. Variation in polygons area relates to dispersion and density of mesquite as reflectivity into pixel size. Polygons in each satellite image were counted and grouped into classes ranging from less than 1 to 10 pixel which is 30x30 meter area in Landsat images with corresponding frequencies. Usually Landsat ignore pixel less than 30x30 m. Polygons exceeding 10 pixels were counted, shown in graphs, but not grouped into classes. The mean and the standard deviation were calculated for grouped data of mesquite. Physical properties of the Delta were obtained from maps provided by ACSAD (2005) including physiographic units (Fig.3 A), soil salinity (Fig. 3 B), phosphorus (Fig 3 C), low exchanged sodium (Fig. 3 D) and high exchanged sodium (Fig. 3 E), soil productivity (Fig. 3 F) and degree of underground water potentiality (Fig. 3 G). They were overlapped on satellite images (Figs. 4; 6; 8) to link mesquite expansion with the Delta's physical properties. Partial correlation equation, $R_{1203} = r_{12} - r_{13} r_{23} / \sqrt{(1 - r_{13}^2) (1 - r_{23}^2)}$, is used to correlate Low and high temperature of the Delta from 1995 through to 2008, with grouped data of mesquite expansion.



*Fig.2: A: Mesquite in 1976.
Source: ACSAD, 2005*



*Fig.2 B: Mequite in 1986.
Source: ACSAD, 2005*



Fig.2: A: Mesquite in 2000.
Source: ACSAD, 2005

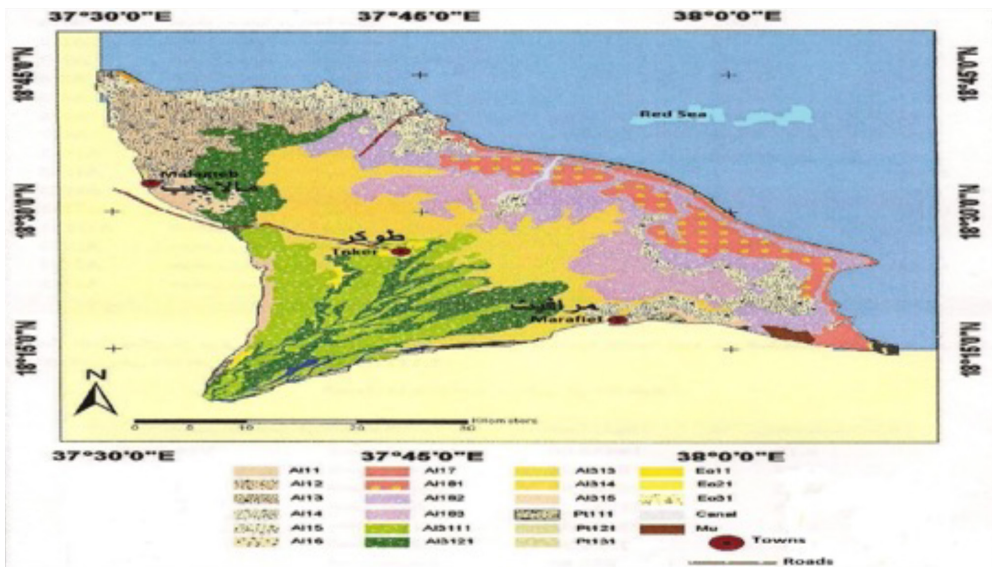


Fig.3 A: physiographic in 1986.
Source: ACSAD, 2005

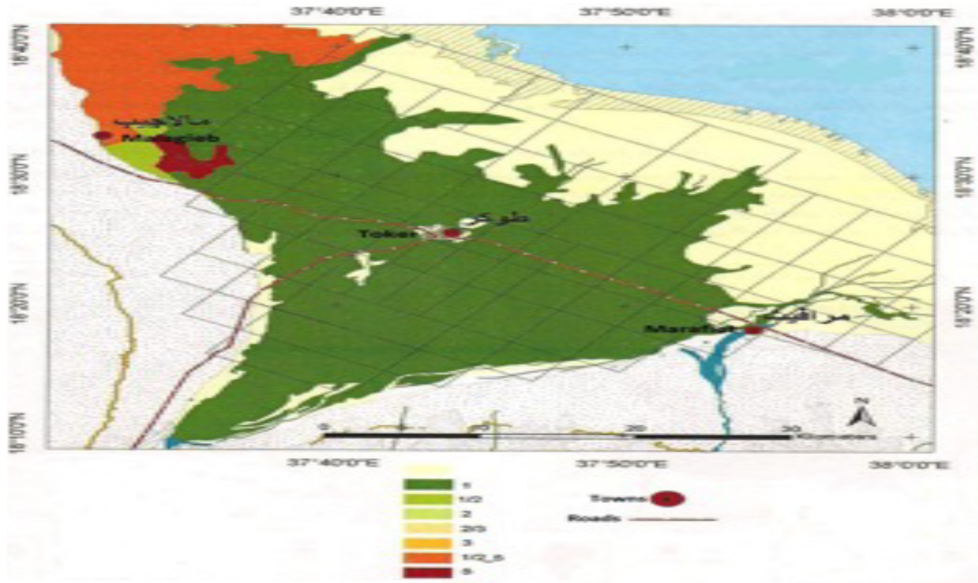


Fig.3: B: soil salinity.
Source: ACSAD, 2005

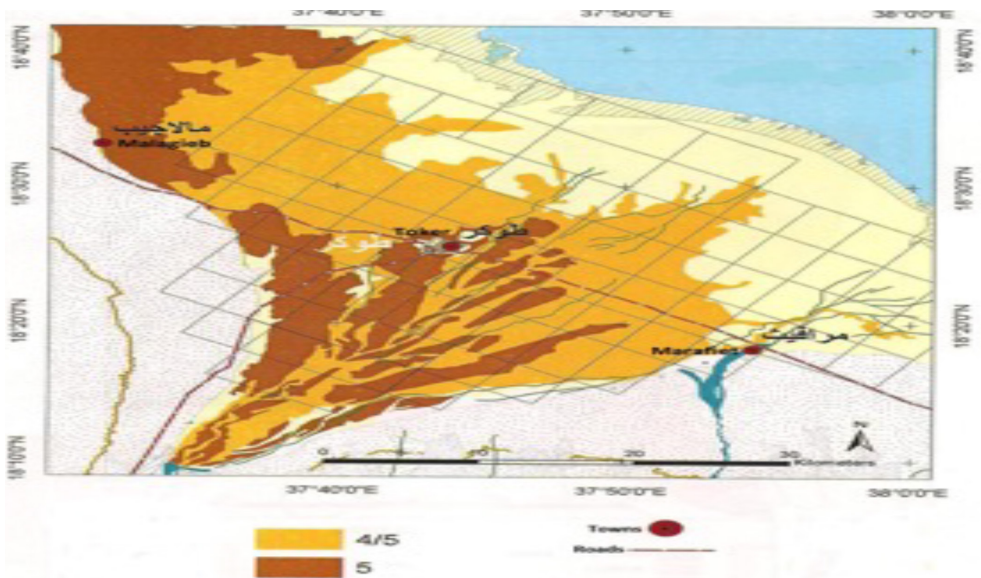


Fig.3 C: low exchanged sodium.
Source: ACSAD, 2005

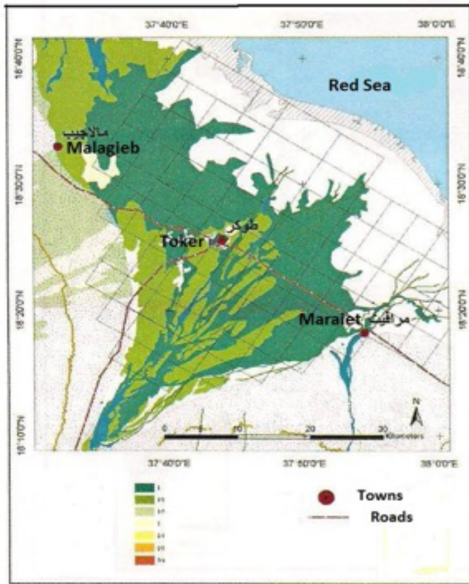


Fig.3: D: low exchanged sodium.
Source: ACSAD, 2005

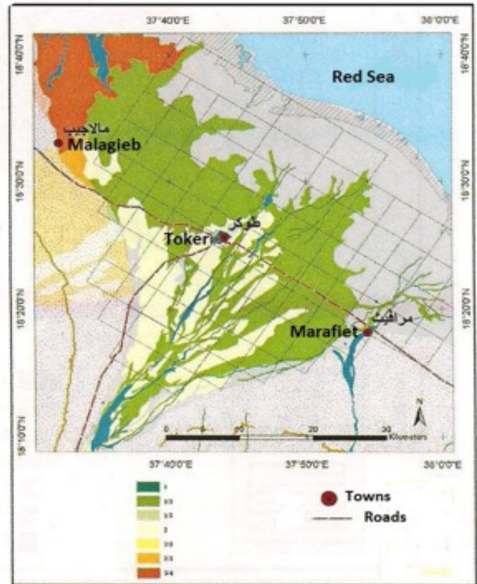


Fig.3: E: high exchanged sodium.
Source: ACSAD, 2005

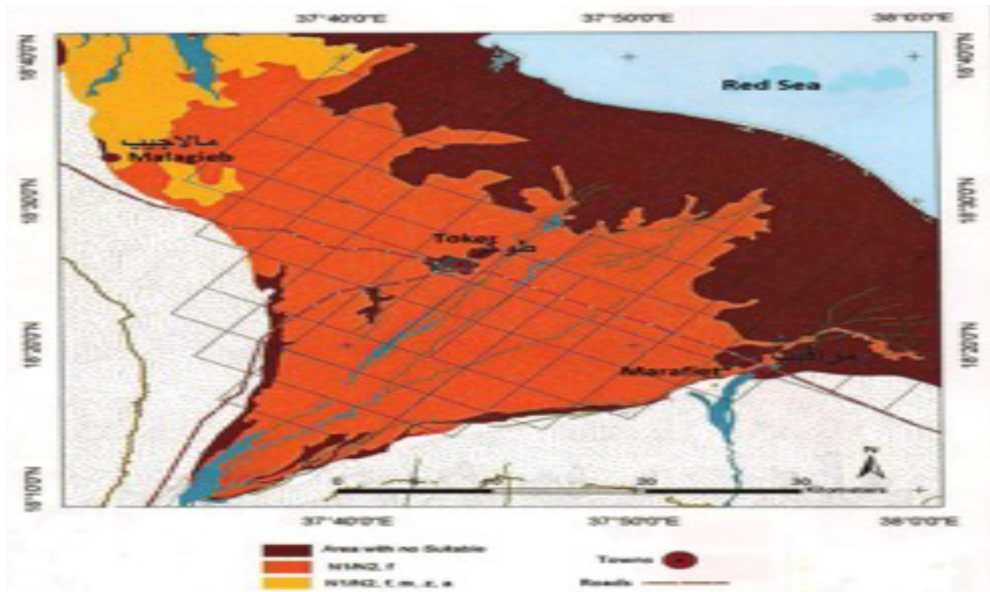
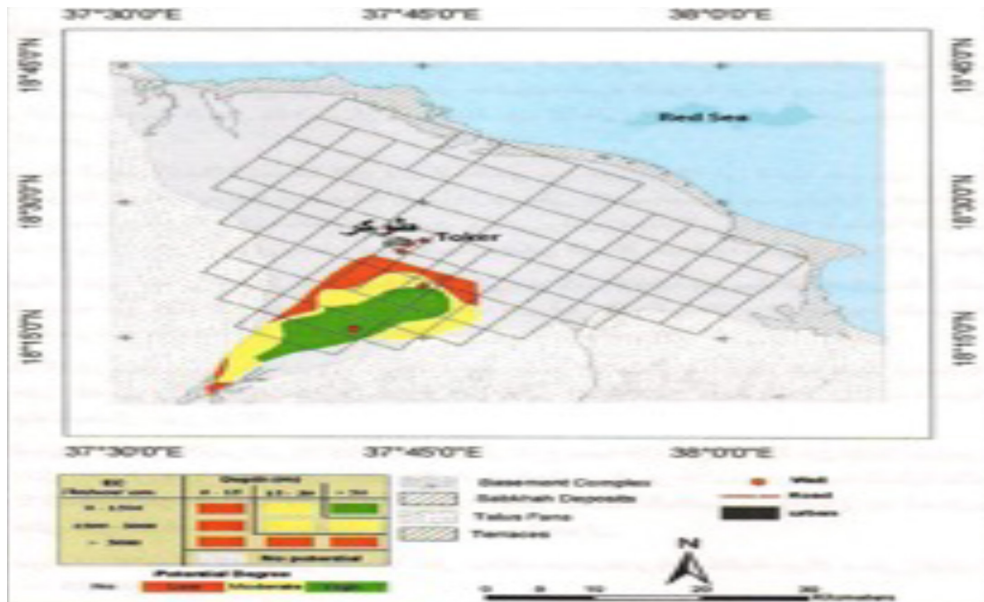


Fig.3 E: soil productivity.
Source: ACSAD, 2005



*Fig.3: G : underground water potentiality.
Source: ACSAD, 2005*

Physical characteristics of Toker Delta

On the Red Sea coast of Sudan (Fig.1), Toker Delta locates between 18° 18' - 18° 40' N and 37° 30' - 37° 55' E. It has an area of 1624 km² and average slope of 86 cm/km (ACSAD, 2005), an equal axis triangle shape with base line parallels Red Sea coast. It is classified as river terraces fan and divided into 15 physiographic units (table 1). Deltaic deposits areas (48% of the total area), areas of interface between Delta deposits and coastal marine deposits (0.11 million hectare) and man-made barrier (28% of total area) are the major physiographic units.

Table 1: Physiographic units of Toker Delta

Map Index	Physiographic unit	Area (hectare)	%
A111	Relatively high plain areas	1516	0.72
A112	Relatively low plain areas	70	0.03
A113	Mixed deposits salty marine areas	18007	8.31
A114	(Swamps and salty water areas (sabkhas	18609	8.59
A115	Mangrove habitat areas	4571	2.11
A116	Superficial mixed deposits	1633	0.75
A117	Coastal sands	6394	2.95
A1181	Man made barrier – climax areas	15552	7.18
A1182	Man made barrier – front slope areas	23972	11.06
A1183	Man made barrier – back slope areas	20881	9.64
A13111	Relatively high areas of Delta Toker	29225	13.49
A13121	Relatively low areas of Delta Toker	32065	14.80
A1313	Depositional basin of the Delta moderate elevation	18927	8.73
A1314	Depositional basin of the Delta moderate elevation	25232	11.64
A1315	Depositional basin of the Delta moderate elevation	2699	0.72
Total		216699	

Source: ACSAD, 2005.

Barak River inundates the Delta seasonally. It comes splashing with high suspended sediment load of 250 to 980 million M³ of silt (ACSAD, 2005). The highest estimated discharge is 800 million m³, the moderate is 500 million M³ and the lowest is 200 million M³ of water and nearly 60% of this amount of water is discharged into the Red Sea (ACSAD, 2005). The coefficient of surface runoff is 0.012 and average annual deposition of silt is 15 cm (ACSAD, 2005). About 70% of the rain falls down during November to January at 100-150 mm. Soil temperature system is hyperthermic where average annual soil temperature is 22° C and temperature difference between summer and winter months exceeds 5%. Soil humidity system is typical aridic. Average humidity is 59%, temperature range is 22 – 46 C⁰ while average sunshine ranges 6 to 8 hours a day (Meteorological Records, 2008).



Fig.1: location of the study area shown in red “Res Sea Coast in Sudan”

Source: Institute of Humanity and Nature, 2007

The aquifer is composed of alluvial sediments zone of dry silt and sand, underlain by freshwater aquifer zone with thickness of 10 to 80 m and a surface area of 200 km² (El Gaily, 2007). This is underlain by thin layers transition zone of brackish water bearing layers. This zone is underlain by saline water-bearing formations or possibly clayey layers with an average thickness of 15 m (El Gaily, 2007). Underground water records highest in upper Delta and decreases gradually till sea level. This hydraulic gradient agrees with earth surface gradient of the Delta which lowers down from highest elevations of Baraka River towards Red Sea coast. Hydraulic gradient is estimated at 4.6% for upper Delta, 1% - 5% for the mid Delta and 0.5% for lower Delta. Annual groundwater discharge is 32 million m³ (El Gaily, 2007), being recharged annually by 31 million m³ by River Baraka. Underground water occurs at depths of 14 to 16 m (ACSAD, 2005). Fresh water occurs floating over moderate to high saline water and the thickness of the saturated aquifer with fresh water reaches 45 m in the southern part of the Delta. Thickness of this zone decreases northeastwardly. Underground water salinity changes vertically and horizontally. This is particularly in sand formations due to mixture between fresh and saline waters. Annual movement

rate of underground water from Baraka River towards Toker Deltas estimated at 75 million M³ (ACSAD, 2005).

Mesquite was firstly introduced in Toker Deltain 1962 by Forestry Authority to combat wind erosion caused by "Ahataib" winds and to stabilize sand dunes. Schlensh and *P. juliflora* mesquite species dominate the Delta (Abdulmagid, 2008) where their height range between 4 to 7 meters and stem thickness ranges 12 to 20 cm with 600 trees per feddan (Asim, 2007).

Time – space aspects of mesquite expansion

In 1976's satellite image (Fig. 2 A), mesquite appears in red concentrating in central Delta and taking the form of small discrete patches. GIS processing of figure (2 A) depicts mesquite in yellow polygons (Fig. 4). Overlapping figure 4 on physiographic units of the Delta (Fig. 3 A and table 1) gives depositional basin of the Delta with moderate elevation (A1314), relatively low areas of the Delta (A13121), swamps and salty water areas or sabkhas (A114), front slope areas (A1182) as the major physiographic units occupied by mesquite. Areas with high potential degree of ground water were also occupied by dense mesquite opposite to areas with no ground water potentiality degree (Fig.3 G).

Polygons of Figure 4 were summarized into frequency classes ranging from less than 1 pixel up to 10 pixels (Table 2). Out of 103 polygons, there are 55 polygons with less than 1pixel (- 900 m²) representing 53.3% of total number of polygons while 12.6% of polygons' area ranges between 1 pixel to less than 2 pixels. Generally, 67.9% of the area occupied by mesquite does not exceed two pixels. Mesquite tends to concentrate into very small areas with mean value of 1.3 pixels. The standard deviation value of 4.1 depicts somehow big difference into dispersion of frequencies around this mean value. Mesquite areas are asymmetrically distributed and positively skewed. For polygons exceeding 10 pixels (8100 m² – 9000 m²), there are 26 polygons representing 25.2% of the total percent of polygons (Fig. 5). They are asymmetrically distributed with one high tip, have very big range value of 759 pixels (770 - 11) indicating to wide area variation into adjacent locations occupied by mesquite.

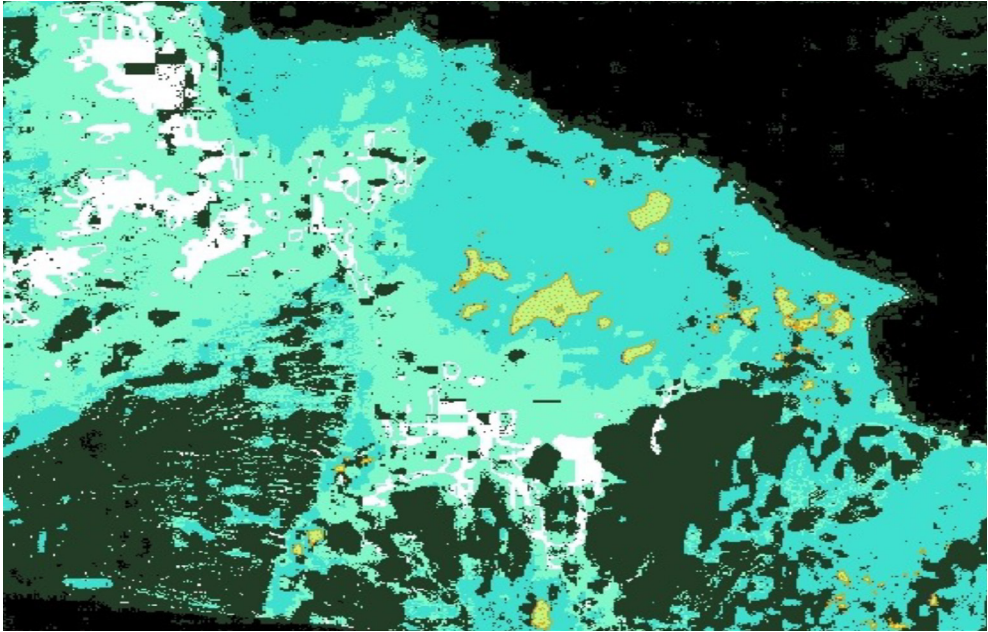


Fig. 4. GIS processed satellite of mesquite, 1976

Table 2: Frequency distribution of polygon area, -1 pixel 10 pixels, occupied by mesquite in 1976

RANGES IN PIXEL																							
-1 m ² 900 -		1-2 m ² - 1800 900 m ²		2-3 - m ² 1800 m ² 2700		3-4 - m ² 2700 m ² 3600		4-5 - m ² 3600 m ² 4500		5-6 - m ² 4500 m ² 5400		6-7 - m ² 5400 m ² 6300		7-8 - m ² 6300 m ² 7200		8-9 - m ² 7200 m ² 8100		9-10 - m ² 8100 m ² 9000		10+ m ² 90000 +		total	
.Freq	%	.Freq	%	.Freq	%	.Freq	%	.Freq	%	.Freq	%	.Freq	%	.Freq	%	.Freq	%	.Freq	%	.Freq	%	.Freq	%
55	53.3	13	12.6	3	2.9	0	0.0	2	1.9	0	0.0	1	0.9	3	2.9	0	0.0	0	0.0	26	25.2	103	100.0

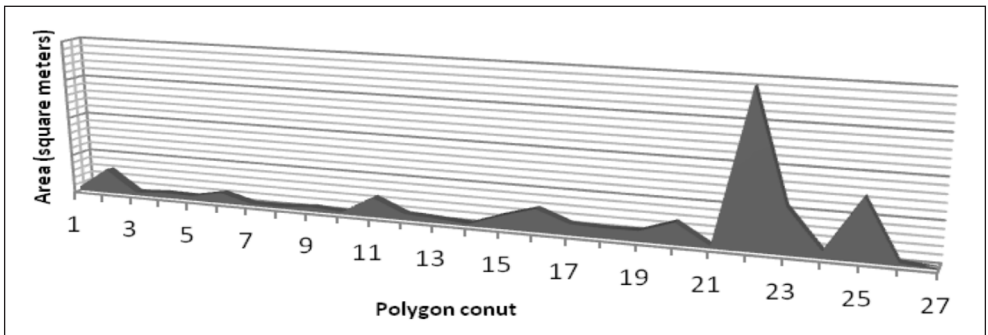


Fig.5. Frequency distribution of polygon s exceeding 10 pixls in Delta Toker 1976

In 1986's satellite image mesquite appears in green (Fig. 2 B). It expanded taking the triangle shape of the Delta. GIS processing of figure (2 B) depicts mesquite in light green polygons (Fig.6). Overlapping figure (Fig.6) on physiographic units of the Delta (Fig. 3 A and table 1) adds back slope areas A1183, coastal sands A117, relatively high areas A13111, relatively low areas A13121 and areas characterized by low and high to moderate underground water potentiality physiographic units, to those areas already have been occupied by mesquite in 1976. Polygon areas of figure 6 were summarized into frequency classes of less than 1 pixel up to 10 pixels (Table 3). This gives 891 polygons ranging from less than 1 pixel up to more than 10 pixels. Out of 891 polygons, there are 468 polygons have an area less than 1 pixel ($- 900 \text{ m}^2$) which represents 57.3% of total number of polygons while 18.0% of polygons' area ranges between 1 pixel to less than 2 pixels. Generally, 75.3% of the area occupied by mesquite does not exceed two pixels. Mesquite tends to concentrate into very small areas with mean value of 1.4 pixels. The standard deviation value of 1.8 depicts very small difference into dispersion of frequencies around this mean value. Mesquite is asymmetrically distributed and positively skewed. Polygons' areas exceeding 10 pixels (8100 m^2 – 9000 m^2) represent 9.8 % of the total percent of polygons (table 3). They were counted as 88 non sequential polygons with different frequency in area (Fig. 7). Mesquite polygons are symmetrically distributed with one high tip in far frequency count of 83, have very big range value of 33462 pixels ($33473 - 11$) indicating to discrepancy between some values.

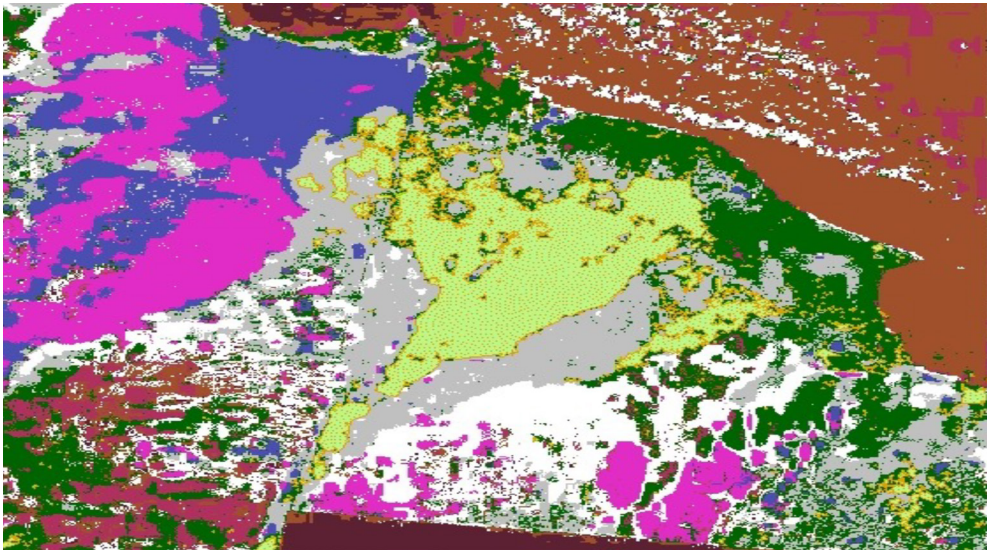


Fig. 6. GIS processed satellite of mesquite, 1986

Table 3: Frequency distribution of polygon area, -1 – 10 m2, occupied by mesquite in 1986

RANGES																							
-1		1-2		2-3		3-4		4-5		5-6		6-7		7-8		8-9		9-10		10+		total	
m ² 900 - - 1800 m ²		m ² 900 - 1800 m ²		- m ² 1800 m ² 2700		- m ² 2700 m ² 3600		- m ² 3600 m ² 4500		- m ² 4500 m ² 5400		- m ² 5400 m ² 6300		- m ² 6300 m ² 7200		- m ² 7200 m ² 8100		- m ² 8100 m ² 9000		m ² 90000 +			
.Freq	%	.Freq	%	.Freq	%	.Freq	%	.Freq	%	.Freq	%	.Freq	%	.Freq	%	.Freq	%	.Freq	%	.Freq	%	.Freq	%
510	57.2	160	18.0	57	6.4	24	2.7	15	1.7	11	1.2	1	0.1	9	1.0	8	0.9	8	0.9	88	9.8	891	100.0

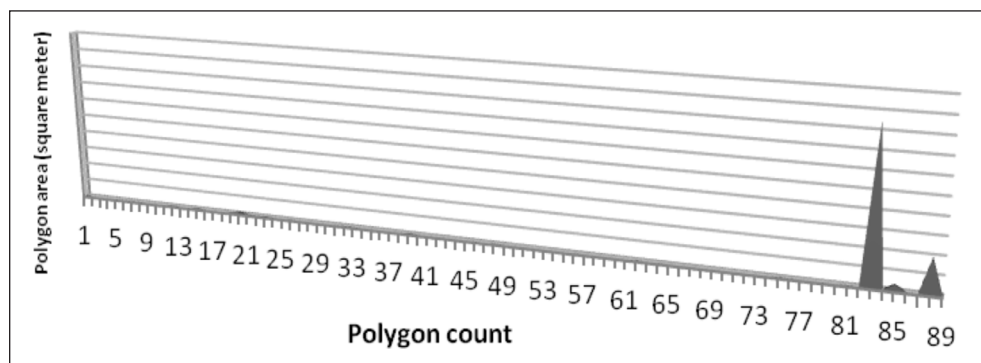


Fig.7. Frequency distribution of polygons exceeding 10 pixels occupied by mesquite in Delta Toker 1986

In 2000's satellite image mesquite appears in green (Fig. 2 C). It fully took the triangle form of the Delta. GIS processing of figure (2 C) depicts mesquite in light green polygons (Fig.8). Overlapping figure (Fig.8.) on physiographic units of the Delta (Fig. 3 A and table 1) adds to those physiographic units already occupied in 1976 and 1986, depositional basin of moderate elevation (A1313), man-made barrier – climax areas (A1181), mangrove habitat areas (A115) as new occupied ones. Mesquite also occupied areas composed of basement rocks and talus fans in dense patches, areas characterized with high, moderate and low ground water potential as well as no potential ground water areas (Fig. 3 G). Polygon areas of figure 8 were summarized into frequency classes ranging from less than 1 pixel (- 900 m²) up to 10 pixels (Table 4). There are 1016 polygons of less than 1 pixel up to 10 pixels. 732 polygons out of them have less than 1 pixel representing 72.0 % of total number of polygons while 14.7 % of the polygons have 1 pixel to less than 2 pixels. Generally, 86.7 % of

the area occupied by mesquite does not exceed two pixels. Mesquite tends to concentrate into very small areas with mean value of 0.92 pixels. The standard deviation value of 1.2 depicts very small difference into dispersion around this mean value. Mesquite is asymmetrical distributed and positively skewed. Polygons exceeding 10 (8100 m² – 9000 m²) pixels represent 3.7% of the total percent of polygons (table 4). There are 37 non sequential polygons with different pixels frequency (Fig. 9). They have one very high tip and another small tip, as well as big range value of 14071 pixels (14082 – 11) indicating to wide area variation into adjacent locations occupied by mesquite.

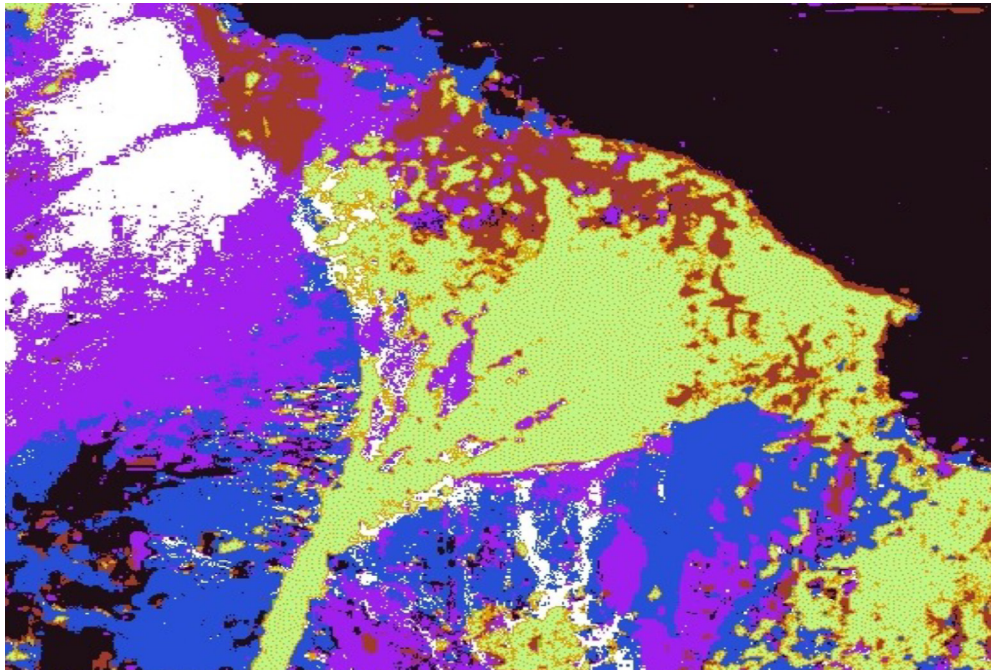


Fig. 8. GIS processed satellite of mesquite, 200

Table 4: Frequency distribution of polygon area, -1 – 10 m2, occupied by mesquite in 2000

RANGES																							
-1 m ² 900 -		1-2 m ² 900 - 1800 m ²		2-3 - m ² 1800 m ² 2700		3-4 - m ² 2700 m ² 3600		4-5 - m ² 3600 m ² 4500		5-6 - m ² 4500 m ² 5400		6-7 - m ² 5400 m ² 6300		7-8 - m ² 6300 m ² 7200		8-9 7200 - m ² 8100 m ²		9-10 - m ² 8100 m ² 9000		10+ m ² 90000 +		total	
.Freq	%	.Freq	%	.Freq	%	.Freq	%	.Freq	%	.Freq	%	.Freq	%	.Freq	%	.Freq	%	.Freq	%	.Freq	%	.Freq	%
732	72.0	150	14.7	44	4.3	23	2.3	11	1.1	6	0.6	4	0.4	9	0.9	1	0.09	2	0.2	37	3.6	1016	100.0

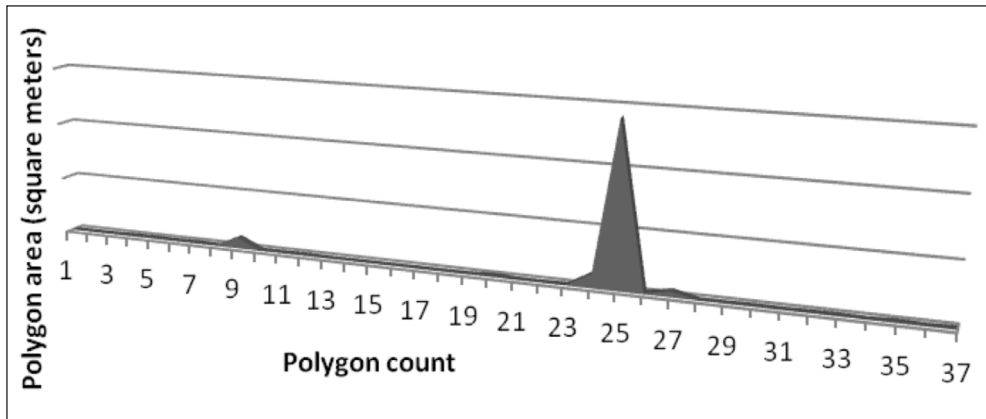


Fig.9. Frequency distribution of polygons exceeding 10 pixels occupied by mesquite in Delta Toker 2000

Specification of mesquite prone areas with physical determinants

Mesquite occupied ten physiographic units out of fifteen (Fig.3 A). This represents 66.7% of the total number of physiographic units of the Delta. They include depositional basins with moderate elevation (A1314), relatively high areas (A13111), relatively low areas (A13121), swamps and salty water areas or sabkhas (A114), depositional basin of moderate elevation (A1313). Man, intervention through building barriers in the front slope areas, back slope area and climax areas also make these areas vulnerable to mesquite expansion. This is as well as areas composed of basement rocks and talus fans.

Chemical properties of mesquite prone areas were summarized in table (5) which was obtained by overlapping satellite images (Figs. 4; 6; 8) on physical properties maps of the Delta (Figs. 3 B; C; D; E; F; G). Mesquite prone areas are characterized by soil salinity of 1 (Fig. 3 B); high levels of Phosphorus of 4/5 and 5 (Fig. 3 C); exchanged sodium values of $\frac{1}{2}$, 1 and 2 (Figs. D and E); high soil productivity of N1, N2 and f (Fig. 3 F) and moderate and low aquifer potentiality (Fig. 3 G). Phosphorus is found in all physiographic units except man-made barrier – climax areas and coastal sands. Exchanged sodium is absent in 5 physiographic units out of 10 and similarly soil salinity (table 5).

Since temperature influences plant growth, partial correlation between polygons with less than 1 pixel up to 10 pixels and high and low temperature (table 6) gives very weak negative correlation of - 0.12. It is expected that an increase in mesquite growth is reversed with temperature decrease, indicating to winter season as more favorable for mesquite expansion in Delta Toker

Table 5: chemical properties of mesquite prone areas

Physio-graphic Units	A1314 Depositional basin of the Delta moderate elevation	A13121 Relatively low areas of Delta Toker	A1182 Man made barrier – front slope areas	A1183 Man made barrier – back slope areas	A13111 Relatively high areas of Delta Toker	A1313 Depositional basin of the Delta moderate elevation	A1181 Man made barrier – climax areas	A114 Swamps and salty water areas ((sabkhas	A115 Man-grove habitat areas	A117 Coastal sands
Soil salinity	1	1	-	1	1	1	-	-	-	-
Phosphorus	4/5	4/5	4/5	4/5	5	4/5	-	5	4/5	-
Exchanged Sodium	1	1/2	-	-	2 1/2	2 1/2	-	3/4 1/5	-	-
Soil productivity	N1, N2, f	N1, N2, f	Area with no suitable	N1, N2, f	N1, N2, f	N1, N2, f	Area with no suitable	N1, N2, f	N1, N2, f	Area with no suitable
Aquifer Potentiality	low	High moderate	low	low	Low Moderate high	low	low	low	low	low

Source: analysis of maps ---- ACSAD, 2005

Table (6): Partial correlation between mesquite polygons (-1 pixel to 10 pixels) and temperature (1995-2008)

Range in pixels	Count (x ₁)	Max Temp ((C° (x ₂)	(Low (C° T e m p (x ₃)	X ₁ ²	X ₂ ²	X ₃ ²	X ₁ X ₂	X ₁ X ₃	X ₂ X ₃
-1	45	35	24.4	2025	1225	595	1575	1080	854
1-2	13	34.8	24.4	169	1211	595	452	312	849
2-3	3	34.8	24.5	9	1211	600	104	72	825
3-4	0	34.6	24.7	0	1197	610	0	0	854
4-5	2	34.7	24.0	4	1204	576	69	48	832
5-6	0	35.0	24.1	0	1225	580	0	0	843
6-7	1	34.5	23.9	1	1190	571	34	34	824
7-8	3	35.1	23.7	9	1232	561	105	69	831

8-9	0	34.6	23.4	0	1197	547	0	0	809
9-10	0	34.7	23.7	0	1204	561	0	0	822
10+	36	34.6	23.2	1296	1197	538	1224	828	802
Total	103	347	239	3513	1206	5739	3563	2443	9145
	$\bar{x} = 9.3$ $\sigma = 15.3$	$\bar{x} = 31.5$ $29.7 = \sigma$	$\bar{x} = 21.7$ $7.1 = \sigma$	$R_{1203} = r_{j2} -$ $r_{i3} r_{23} / \sqrt{(1-$ $(r_{i3}^2)(1-r_{23}^2)$ $0.18 - 0.06 =$ $\times 0.70 / \sqrt{(1-$ $0.18^2)(1-$ $0.70^2)} = -$ $0.06 / 0.49 =$ $- 0.12$					

Discussion and conclusions

The results confirm that mesquite is invading Toker Deltasimilar to El Getaina town and surrounding areas along the White Nile banks in central Sudan ((Yousif, 2005) and to southern Arizona where velvet mesquite began to invade upland grassland environments and is generally associated with very high livestock densities, severe drought, and reduced fire frequencies and is driven principally by ecological changes that permitted mesquite seedlings to establish and persist in upland environments (Arizona Board of Regents. 2009), and to Kiawe Prosopis pallid in Hawaii which became a pest species, invading, competing and overwhelming native grass species and woody plants (The Maui Plant Chronicles. 2011) and with Western Gulf Coastal Grasslands eco-region in Mexico and USA, which was covered with mesquite brush (worldwildlife, 2011). The rapid increase of mesquite expansion in Toker Deltabetween years 1976 and 2000 conforms to Western Australia where the shift from grass to mesquite domination had been rapid (Robinson, 2008). The results estimate dispersion into very small areas with mean value not exceeding 1.0 pixel (- 900 m²) agreeing with Western Australia where the rate of patch recruitment was high in all land types including stony flats, red-loamy soils and the riparian zone (Robinson, 2008).

Results confirm that mesquite is well adapted with places with high physical potentialities. This is confirming similar findings in previous research by Abdulmagid (2000) who found that the well adapted places were characterized with high moisture content including drainage lines, irrigation canals, bridge inlets and outlets and irrigated farm lands, bare land unexploited by agricultural or forestry activities and neglected lands having reliable

humidity for growth. It also conforms to the effect of velvet mesquite *Prosopis velutina* on soil moisture in Sonoran Desert of central Arizona which changed from positive in the upland to negative in the terrace (John et al., 2007). It also conforms to Western Australia where the rate of patch recruitment was high in all land types including stony flats, red-loamy soils and the riparian zone (Robinson, 2008). The results also confirm a complex of highly correlated, relative contribution of various physical determinants on mesquite expansion. Mesquite grows in locations characterized by high soil productivity of N1, N2 and f agreeing with the study in southern Great Plains near Vernon, TX where soil carbon and nitrogen content have no significant differences between the communities of the different vegetation types and with where the accumulation of organic matter in soils beneath mesquite reflects gradients in productivity, although flooding in the riparian zone of the largest streams reduces the accumulation of organic matter in surface soils in Sonoran desert landscapes (Sponseller, 2006). The study gives exchanged sodium at 2, 1 and ½ values agreeing with ACSAD (2005) which indicates to less than 6% in all of the layers in Delta Toker, and with exchange sites in several communities within Lower Virgin River Basin (Michael, et al. 2002). Of course, organic matter is prime factor in mesquite growth where ACSAD (2005) confirmed less than 0.5% organic matter in sub-surface layers which agrees with Biggs, et al.(2002) study which revealed that mesquite trees have altered soil organic matter $\delta^{13}C$ pools by the concentration of plant nutrients and the addition of isotopically light litter, elevated total organic carbon, plant nutrient (N and P) concentrations and that growing Karnal grass with mesquite for the 2-yr period reduced soil pH and EC significantly and also improved organic carbon and available N contents, and water infiltration rates and moisture storage in the lower layers of the profile (Singh, et al., 1988). Results indicates to soil salinity of 1 and this agrees with that mesquite appears able to survive and even flourish in soils more saline than 12,800 mg/L and that the roots can apparently continue to extract water from soil with salinities greater than 17,900 mg/L (Wesley et al., 1984) and that mesquite is not impacted by levels of salinity found in the Salt River basin (Richard, 2005). Results revealed that mesquite grows in locations of 4/5 and 5 levels of Phosphorus which enhances its physiological processes related to proper energy utilization (Mike, et al., 2011). Mesquite growth in low areas of ground water potentiality depicts its ability to extend roots deep downwards into the soil. Its growth in areas with abundant soil nutrients

indicates its competition with native grasses and agriculture where base saturation for surface and sub-surface layers in most of the units ranges between 33 and 59 cmol /kg ACSAD (2005). Adaptability of mesquite to the environment of the Delta agrees with Michael, et al., (2003) study on Rhizobial and bradyrhizobial symbionts of mesquite from the Sonoran Desert which suggested adaptation of mesquites to their respective soil environments and diverging from the surface Bradyrhizobium community.

The general characteristics of mesquite expansion in Toker Deltawere are,

1. Nuclei of mesquite growth were depositional basins and relatively low areas.
2. Mesquite grows on all physiographic units, but more excessively in relatively areas low with high depositional and underground water potentiality.
3. The majority of polygons have small area not exceeding 1 pixel (- 900 m²).
4. Polygons less than 1 pixel (- 900 m²) steadily increase opposite to polygons exceeding 10 pixels (8100 m² – 9000 m²).
5. In 1976 the standard deviation depicts somehow big difference into dispersion of pixels frequencies and mesquite areas are asymmetrically distributed and positively skewed. In contrary to 1976, the standard deviation value depicts somehow very small difference into dispersion of pixel frequencies and mesquite is asymmetrically distributed and positively skewed. Similar to 1976, mesquite tends to concentrate into very small mean value and standard deviation depicts small difference into dispersion and mesquite is asymmetrical distributed and positively skewed.
6. Each satellite image with polygon distribution exceeding 10 pixels has at least one high tip indicating to mesquite tendency to form denser clusters.
7. There is a multitude of physical factors into mesquite expansion.

This study is limited by lack of fieldwork data that were not included in the analysis, but the usefulness of these results is that they investigate a more

complex interplay of variables physical into mesquite expansion in Delta Toker. Current government commitment in Sudan suggests eradication of mesquite in Delta Toker. The Kuwait fund for eastern Sudan in collaboration with the Government of Sudan and international donors and investors conference for development of east Sudan, Kuwait 1-2 Dec. 2010, have also provided good information about potentials, mesquite and high siltation problems in the study area (www.kuwaitfund.org/eastsudanconference). Sudan productive capacity recovery program (SPCRP2010) has studied Toker Delta agricultural scheme and made available good information on mesquite problem and methods of combating its future expansion. The study on production of vegetable for export in Toker Delta has highlighted the problems of agricultural production as due to mesquite expansion (Sudan economy.com.2010). Rehabilitation of Toker Delta sponsored by Government of Sudan has also highlighted the scheme's problems and strategies for how to overcome them.

Given these chances, as well as the limitations of our paper, we propose that this study is replicated using future statistics ---as well as in other African settings.

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7

Conflict on Natural Resources in the vicinity of Red Sea Basin, Case Studies from Gedarief state

Conflict on Natural Resources in the vicinity of Red Sea Basin, Case Studies from Gedarief state

Natural resource-based conflicts are defining characteristics of arid and drought-prone areas in Africa. The causes of these conflicts are many, such as demographic change; natural resources competition; developmental pressures and structural injustices. The combination of demographic change and the limits to sustainable harvesting of renewable natural resources (forests, water bodies, grazing areas, wildlife and agricultural land) are often cited as the underlying cause of conflict over natural resources, both among community groups, and between community groups and outside public and private organizations (Warner, 2000). The short-term adverse impact of conflicts can range from a temporary reduction in the efficiency of resource management regimes, to the complete collapse of initiatives or abandonment of government or donor-sponsored projects. In extreme cases conflicts over natural resource management can escalate into physical violence.

The modern history of Africa is characterised with foreign invasions by regional and international powers seeking to gain control of the Continent's strategic location and rich natural resources. Prior to those invasions, African societies used to live on subsistence economy of traditional agriculture and grazing at times when population was small and no competition for resources is triggering on. During the colonial period, from late 19th century through the mid of the 20th century, African economies are incorporated into the world market economy through production of cash crops and mining of precious minerals for export. Many of the traditional African communities saw that a form of violation of their rights on resources of land and pastures. Colonial socio-economic policies had caused regional disparities of development in many places as they targeted easy access areas and left the illiterate majority as either pastoralists seeking for pastures or traditional agriculturalists producing for self-subsistence. Tribalism among Africans enhanced tendency towards tribal ownership of resources other than by a Nation.

Post-Independence African did not succeed to overcome such burdens left by colonial powers and therefore is challenged with very violent resource-based conflicts. Many of the conflicts concentrated in poor and divided countries that possess only one or two major sources of wealth and in the regions with a precious pool of natural resource such as Sierra Leone whose

natural resources have been a source of conflict from 1991 to 2000 due to the resources got from the illegal sales of diamonds (Nnane, 2007). Oil discoveries and exploitation have similarly led to many conflicts in Nigeria, Angola, Chad and Sudan, for example (le Billon, 2010). Severe scarcities of water and arable land could provoke conflict over the distribution of shared water resources in Africa (Shatima and Tar, 2008). The West African sub-region has witnessed resource conflicts involving sedentary farmers and mobile pastoralists. There is a history of pastoral communities fighting for scarce resources in southern parts of Ethiopia, Northern Kenya, parts of Somalia and the Sudan (Mekonnen, 2006). Such conflicts take place although “Pastoralists have interacted with sedentary farmers for millennia, with established practices of trade and symbiotic production such as grazing of livestock on farmers’ fields before planting seasons. However, both population growth and increasing commodity production have led to the expansion of agriculture on formerly shared grazing lands, and have increased tension and conflicts between these groups in many parts of the world” (Fratkin, 1997).

Of particular concern are conflicts in Sub-Saharan Africa, including Sudan, which is more vulnerable to water stress than any other regions. In this region, about 64 percent of Africans rely on limited and highly variable water resources where 25 percent of them suffer from water stress. They also rely on croplands inhabit the driest regions where some 40 percent of the irrigated land is unsustainable and 96 percent of agriculture is rain-fed. Soil nutrient depletion is a more pressing problem than drought and nearly 13 percent of the population in Africa experiences drought-related stress once each generation (Tatlock, 2006).

Drought is one of the causes of conflict. Many areas affected by drought are arid and semi-arid. When drought occurs in such areas, the land yields no crops and water is insufficient for human consumption as well. People compete for the meager available resources. Pastoral communities increase their movements during drought where different pastoral groups move to the same place and want to use the same scarce resources, which cause conflicts between the two communities. At the same time a period of severe drought led to large-scale environmental degradation, population displacement and urbanization.

In addition to drought, there are economic globalization; unsustainable consumption; population growth and economic warfare in poor and developing countries (Klare, 2001). The growing internationalization of finance and trade is having an effect on the demand for and consumption of basic resources. Globalization increases the demand for resources through the spread and acceleration of industrialization. Although the global stocks of most vital materials are sufficient for current requirements, the consumption of many of them is rapidly growing especially for water. The world's human population is expected to grow by about three billion people between now and 2050. Obviously, many of the countries with the highest levels of population growth are located in areas where the availability of some vital resources is in doubt, especially true for water and arable land.

Resource-based conflict constitutes one of the most serious challenges facing many regions in Sudan. Traditionally, resource-based conflict has been represented by the old competition between farmers and pastoralists over water and land resources. The conflict in Darfur was over water and grazing rights (Schanche, 2007) where the areas of the Fur, Birgid, Berti and Daju tribes then became targets for waves of displaced groups from Northern Darfur, especially the Zaghawa and various camel pastoralists whose traditional grazing lands had suffered (Ayoub, 2006). Conflicts over resources take place at community local levels, but they are often escalated by population and climatic factors and by the state policies. Population increased from 26 million to 30 million by the year 2008 (Ministry of Health, 2008). The hyper-arid region of Sudan is characterized by high year-to-year variability in rainfall leading to extreme seasonality/irregular distribution of rainfall over the year and there are marked tendencies for some months to become wetter, and indicating changing intra-annual rainfall variability and thus monthly rainfall erosivity (Elagib, 2010). Rainfall depletion has been most severe in semi-arid central Sudan where between 1921-50 and 1956-85 annual rainfall has declined by 15 per cent, the length of the wet season has contracted by three weeks, and rainfall zones have migrated southwards by between 50 km and 100 km (Hulme, 1990). Rainfall decline had been in the magnitude of 30-40 per cent (Ayoub, 1999).

Understanding conflicts in Sudan requires attention to the state and the institutional framework within which conflicts take place (Assal, 2006). These

conflicts have many causes where at the root of each conflict are questions over the control and distribution of resources (Ayoub, 2006). Due to the prolonged nature of conflicts over resources in Sudan, conflicts take on political side which is threatening the entity of the country. In eastern Sudan, the new level of native administration created for the Rashaida tribe, gave them administrative power without land ownership. In the Blue Nile state, the new traditional administration status created for Fellata tribe, originally from West Africa, fought the indigenous Funj and Hamag tribes. The main political movement of the Nuba Mountains stated one of its main objectives is the "implementation of a land reform policy for the benefit of the indigenous farmers of the Nuba Mountains and the eradication of the feudalistic land policies and relations of production from all forms of exploitation" (Ayoub, 2006). The scarcity of land is also a result of the population movements, both from mechanized farming and from the war involving southern tribal militias, and is a prominent feature of the Beja insurgency in eastern Sudan. These conflicts could be situated within the current government policy of governance and development which imposed sovereignty of the center over the periphery. This led to the distorted idea among the peripherals that power and wealth are unequally distributed although resources are adequate, but was unsustainable, due o inappropriate policies of development.

However, there are some of the knowledge gaps regarding resource-based conflicts in the literature about Sudan. This work might contribute to bridging some of these knowledge gaps. This might be done by achieving the main objective of this study which is to examine types and factors of natural resources-based conflict in eastern Sudan by taking the example of the two villages of Sinaibra and Id el Tien, south of Gedaref Town. In addition, there is a necessity to curb such conflicts which threaten the social fabric of the Sudanese community and its political entity. Therefore, the author proposes the "triangle of environmental surveillance model" that could be useful to equilibrate between human activities, the environment capacity and resource utilization. This might help to achieve resource sustainability and better understanding and explaining resource-based conflicts in the study area. This is particularly that the model is dynamic one which could be developed and updated according to occurring conflicts. The time dimension to fit in the model considers early intervention when resource –based conflicts take place so as to equilibrate between man benefits, environment capacity and

resource utilization. The space dimension firstly considers conflicts occurring at the micro level of a place that could be a field or a village. There should be linkages between the three components of the model to work effectively. This requires cooperation of grass root society, local governance and national government. The implementation of the model could be hierarchical, starting with man then the environment and lastly how properly organize resource utilization according to the foregoing two components, man and the environment.

Data and methods

Gedaref state is located at 34-36° E, bordered by states of Kassala, Sinar, Gezira and Khartoum from the north, south, west and northwest sides respectively and by the Ethiopian borders from the east (Fig. 1). Gedaref state is part of the Butana region which is a plain surface intermitted by dispersed hills covered with alluvium. Topography of Gedaref state includes three major units. Firstly, are the highlands and isolated mountains in the southeast part, secondly, plain area dominating the state characterized by clayey soil (45-80% clay particles) either flat or slow sloped, and thirdly, Wadis (valleys) area including depositional areas around seasonal rivers like Atbara and Rahad. The two case study villages of Sinaibra and Id el Tien belong to Gedaref locality and located south of Gedaref town by 40 km. The two villages are the homeland for the Arab tribes of Bawarda, Fadnia, Lhwien, Muslamia, Muashra, Bani Aamir, Taaysha, Aarkien, Gaalien, Rikabia and migrants from Darfur and west Africa similar to many parts of eastern Sudan. In addition to official Government administrative system in Gedaref area, population are also under power of traditional administrations holding names of the major tribes living in the area and dates back to hundreds of years.

The fieldwork survey was conducted during 2 - 4 November 2009. A questionnaire was designed including data on some socioeconomic and demographic aspects of the two villages' populations, land tenure, relations between population groups, and aspects of conflicts between the farmers themselves, between farmers and herders and between farmers, herds and scheme landlords. In addition, perspectives of the respondents for resolving natural resources-based conflicts were included. Moreover, observations techniques were applied in addition to direct interviewing with some elder people and the heads of the tribes' representing farmers and herders, Local government officials, representatives of operating banks and companies on

agricultural crops and animals in Gedarief Bourse, as well as collection of relevant office data.



Figure.1: Location of the study area

The two villages extend longitudinally from north to south in accordance with Gedaref – Galabat highway which reaches Sudan-Ethiopian border. Morphology of the two villages is distinguished by irregular narrow roads, houses are mere huts built by straw and mud and lacking numbering. Therefore, it was difficult to apply random sampling techniques for the choice of the respondents whom were therefore chosen according to their accessibility during time of the survey. The sample size was 50 households representing 20% of total households in the two villages according to Sudan Census (1993). Respondents were mainly the heads of the households who were either males or females and mainly farmers or herders or combine

farming and keeping animals. Data was manually tabulated and treated statistically to get frequencies and percentages. In addition, relevant office data collected during the fieldwork was used and indicated where appropriate in the results section.

Conceptual modeling of the research results was based on Tacconi' (2000) categorization of types of conflicts into micro-micro (among community groups) and micro–macro (between community groups and outsiders), and on some types peculiar to the study area. This was supported by the definition of a model which expresses some facts intending for the explanation of some prominent characteristics (Yeates et al., 1971) and as a constructive view or composition of some information (Coler et al., 1968).

Types of the economy

The economy of the study area is agriculturally based where farmers and herders constitute 68%, agricultural – based traders 2%, government employees 10% of the households surveyed; while those informally engaged into agricultural works and locally called "free workers" constitute 20% of the population surveyed. This last segment is reflection of the nature of this economy which thoroughly depends on subsidiary agricultural wage labor force. Farmers are mainly producing Dura (sorghum vulgare) and sesame for marketing and some food crops for their own and usually join between agriculture and animal keeping. Land tenure system among the two villages population included individual ownership "Hiaza" (68%), inherited land "family share" (12%) and land renting (20%) from landlords. Land renting is usually highly charged (34%) and subject to changing of area allocated annually for cultivation by landowners (16%). This is partially due to the influence of common ownership of land by inheritance (8%), fluctuation of rainfall (8%) and delaying / non-paying of rent charges (8%) and although 76% of the respondents concerned with this question did not reply to that issue in the questionnaire, direct interviewing revealed common consensus with these explanations.

This agricultural economy of the study area is historically associated with introduction of mechanized crop production schemes (MCPS) in Sudan. Because the Gedarief area is a wide flat grassy plain deep fertile soil, it was chosen for the mechanized crop production schemes as it had a long tradition

of Dura production. It was just estimated after the Second World War that of the 100000 tons of Dura marketed annually in the Sudan; 30000 tons came from the Gedarief area (Jefferson, 1949). Of course, the current total market for dura in Sudan is dynamic, but still Gedarief area's share of the market occupy the first rank. In the Five – Year Post War Development Program of 1946 – 1951, mechanization of Dura production in Gedarief was a major achievement. Many parts of this grassy area were normally uncultivated because of the shortage of drinking water during the dry season, and it was anticipated that mechanization of production would solve this difficult problem by reducing the labor force required in Dura production. The 1970 Investment Act and 1990 Investment Act enabled the expansion of the mechanized farming and by the year 2005 the total area under mechanized farming had increased fifteenfold (Ayoub, 2006).

Herders and grazers are the other segment of the economy of the study area. Some of these herders and grazers, similar to farmers, combine seasonal farming with livestock-raising and are known as agro-pastoralists. Pastoralism was a traditional way of life in the study area which was very famous all over the Sudan by its Pastoral Poets like el Hardalou Poet.

Pastoralism and semi- Pastoralism in the study area are forms of natural resource use and management that comprise movements ranging from year-round camel breeding and long-distance migration, to seasonal movements over shorter distances. Generally, there is a decrease in nomads in Gedarief area from 3.7 % in 1983 to 1.3% in 1993 (MFEP, 1995) and is expected to be more decreased thereafter.

In Gedarief area the total number of animals was 1,630,000 heads in the year 2001 (Veterinary Authority- Gedarief, 2009) and is predicted to increase continuously. The average size of animal ownership per household in the two villages studied is 3 for goats, 5 for sheep and 2 for cows. Landlords also used to keep animals in their schemes depending on farm remnants and fodder for feeding after the rainy season period while depending also on nearby pastures during the rainy season. People of the two villages do not keep camels which are linked with mobile Arab tribes. Although the holding of animals per household seems small, they are the major source of milk and cash income by sales to provide some family needs for sugar, cloth and medicine.

Types of conflicts

Many types of resource-based conflicts could be distinguished in the study area. Conflicts are occurring among farmers (40%), among grazers or herders (55%) and between farmers and grazers and herders (67%) who are directly involved into utilization of land, pasture and water resources. Farmers are utilizing land and water for agricultural production while herders and grazers are utilizing pastures and water for animal keeping. Farmers work hard to secure high production and productivity of crops to sustain their livelihood either working independently or for landlords. This makes them very keen to utilize all resources of land, water, capital and wage labor force. This leads to disputes among farmers over land resource ownership, land boundaries, latent family and relationship in cases of land inheritance and even more they can be generated by jealousy released to growing wealth disparities among farmers and among relatives living together in the neighborhood due to income differences. However, although many farmers compete for better agricultural production, they usually face high charges and cost of feeding wage laborers in situations of vulnerability to crop failure or low agricultural production. This will, of course, aggravate conflict situation.

Local herders and grazers, including farmers, and mobile herders who come during the dry season looking for pasture in the neighborhood or move for shorter distances restricted by animal passages. Many incoming tribes into the study area have migrated from far north such as Shukria, Rufaa, Lhwien tribes as being pushed by recurring drought onsets, or from southwest such as Kenana and Fellatah tribes as being driven by military conflict in Blue Nile area by Sudan People's Liberation Army "SPLA", or from Red sea including Bani Amir and Hudandawa tribes were also driven by rebellious militia of East Liberation Front "ELF". Good pastures and grazing areas are targeted by all and therefore become overburdened by huge number of animals versus low pasture holding capacity. Herders are confronting among themselves over pastures, water sources and sometimes on boundaries entitled as a grazing area for a particular tribe. They work to increase number of animals in order to compensate for high taxes, charged veterinary services and low animal sales profits.

Historically, there has always been tension along pastoral corridors over land and grazing rights between nomads and farmers, even though the population

was small, as reported by 45.5% of the population surveyed. But recently, some parts of these areas have been caught in a complex tangle of severe droughts and dwindling resources. Disputes flare up between farmers and migrating camel and livestock herders, in search of water and pasture for their animals during the dry season which extends from December up to July. They would sometimes graze on farmers' lands and use their water points. However, intrusion into farms is recorded by 87% of the population and land grabbing by 13% among the surveyed population of the study area. Farmers keep working to protect farms against animal intrusions when crops are at pre harvest and still keeping on restricting using farms remnants by herders. Sometimes disputes occur over lost crops and access to water and pastoralists' routes are sometimes settled by tribal leaders.

Herders have no boundaries for looking for pastures. They mostly consider agricultural lands their open homeland and further motivated by culture of "Badiat el Sudan" Nomads land of Sudan, where land is common share and resource is endless giving. Therefore, many disputes occur between sedentary farmers as resource owners of agricultural lands and these herders who intended to use these resources. The introduction of mechanized farming in vast grassy areas had affected the mobility system of herders. They usually move southwards with the retreat of rainfall and northwards with the advance of the rainy season. Herders have inherited the nomads' norms that the land is theirs. They look at the investors into mechanized agriculture as intruders who occupied their lands. The investors see they have the right to exploit land authorized to them. The conflict here is that of latent type on who have the right first to make use of the land where historical right of herders or the government sovereignty have the right first. In addition, many incoming herders who managed to stay permanently in the study area firstly join between agricultural works and animal keeping in order transferring into the sedentary economy. Later, they either become pure agriculturalists or semi-pastoralists by proceeding into the agricultural economy as they possess animals they can sell and buy land from farmers who have been run out of money or failed to pay bank debts or plan to migrate outside the area.

Local subsidiary workers who live in the vicinities of the agricultural mechanized schemes also confront with farmers and herders, as indicated by 34% of the population surveyed. They are either newly settled traditional

farmers or herders who look for an opportunity into the agro-animal system, or might be those who are mainly nonprofessional farmers or herders but look for any work to get living. They usually stay with their relatives whom they have spent longer periods in the study area or they were imported from different parts of Sudan by landlords during production seasons. They conflict with traditional farmers and scheme owners on farm remnants, drinking water, sharing into job opportunities. They are not formally engaged into the agricultural operations but they are under request when these land owners need them as wage laborers. They struggle for survival by dependency on the available resources with the resident population because of scarcity of cultivable land, obstruction of animal herding routes or in the search for fresh water and grazing land.

In addition, 45% of the population surveyed indicated to conflicts occurring between farmers, herders, grazers against middlemen, companies and market dealers who are not directly involved into agricultural production and animal keeping. Middlemen do their job in farms or places of animal gatherings when they present themselves as market dealers or mediators working with big merchants. They control pricing according to sales prices, taxes and local authority commerce regulations. The establishment of Gedaref Bourse in 2005, introduced companies and banks as new market dealers. They work according to hard currency pricing and world market demand. Calculations of costs of agricultural operations and marketing revenue might be in many situations in a deficit to the farmers. The presence of many dealers generates competition among them which is expected to be for the benefit of local producers, but the situation is opposite to that since these dealers control money flow in the market which enforce these local producers to sell at low prices in order avoid crop loss or damage which might create disputes over unfair distribution of profits between the two sides.

Conflicts also occur between traditional farmers and owners of the scheme "landlords" as indicated to by 25% of the population surveyed. Landlords own big mechanized schemes while traditional farmers own small farms or rent lands from landlords. There are many differences exist between them at farm size, capital invested, use of machines, wage labors, income and facilities for marketing agricultural production and animals. In cases when small traditional farmers work for his own benefit, they will be faced with that,

bank will not finance them as they have no guarantee to pay to return the indebted money in case of crop, or in situations of low production and/or vermin attacks. Because landlords produce hugely and have facilities for storage, they control pricing and have priority for marketing where small producers might be subject to crop damage when storage facilities are not available or are very expensive to meet. For those farmers who work into big landlords' schemes under supervision of resident clients, they get into agreements biased for a landlord. They mostly consider themselves producing for others who own the land. These clients, in order to keep on with their jobs and to express their care for landlords, are very tough which makes farmers feel that as if they are working under slavery or feudal system. Farmers confront on with these clients and complain to their landlords who mostly do not response. Many farmers have abandoned agricultural works to other jobs in the marginal economy of towns of Sudan. In such situations, disputes over unfair distribution of profits and jealousy related to growing wealth disparities between land owners and these farmers are generated.

Conflict between the state, as major supporter of the scheme owners, and the small farmers and herders is the most serious of all as indicated by (70%) of the population surveyed. This is because the state is the authority which introduced mechanized rainfed farming and has often been the authorized body to license for land ownership and has opposed the spontaneous resettlement of many indigenous people when stricken by drought. Mechanized farming as natural resource projects are being captured by élites from outside the study area and/or those who happened to own resources of a higher quality in the study area such as big tribal leaders. The structure and location of the large-scale mechanized farms is a source of recurrent and continuous confrontation. It is interesting to note that during the period of rapid expansion of mechanized farming from 1970 to 1985; more than 20 major regional tribal conferences were organized to solve land disputes between the various groups. Here, many disputes can be distinguished over project management between community groups and outside project-sponsors; or those caused by political influence; or arising from differences between the aspirations of community groups and expectations of commercial companies over the unfair distribution of work and profits all of which are imposed by the introduction of mechanized agriculture in the study area.

the short-term adverse impact of conflicts in the study area have led to deportation of some tribes (18%); increasing penalties (18%); tribal fidelity and hatred (20%); crop damage (20%); land grab (10); animals robbery (9%) and loss of life (5%). People resolve such conflicts through courts (53%); signing agreements between conflicting sides (20%); or use of good reputation mediators "Judiah" such as heads of the tribes or respected persons in the community (12%); or paying kind compensations and money penalty (15%). On the other side, official authorities apply laws.

Because the economy of study area is based on agro-animal related activities and the occurring types of resource-based conflicts are inextricably linked together, conceptual modeling of such conflicts can be presented (Fig.2). The two major types of micro-micro and micro-macro conflicts can be identified. Micro-micro conflicts including those occurring among farmers, herders, and people live in the vicinities of the schemes, landlords and the state that are directly involved into utilization of land and water resources. However, middlemen, companies and market dealers who are not directly involved into agricultural production and animal resources are also identified within micro-micro type of conflicts (Fig.2).

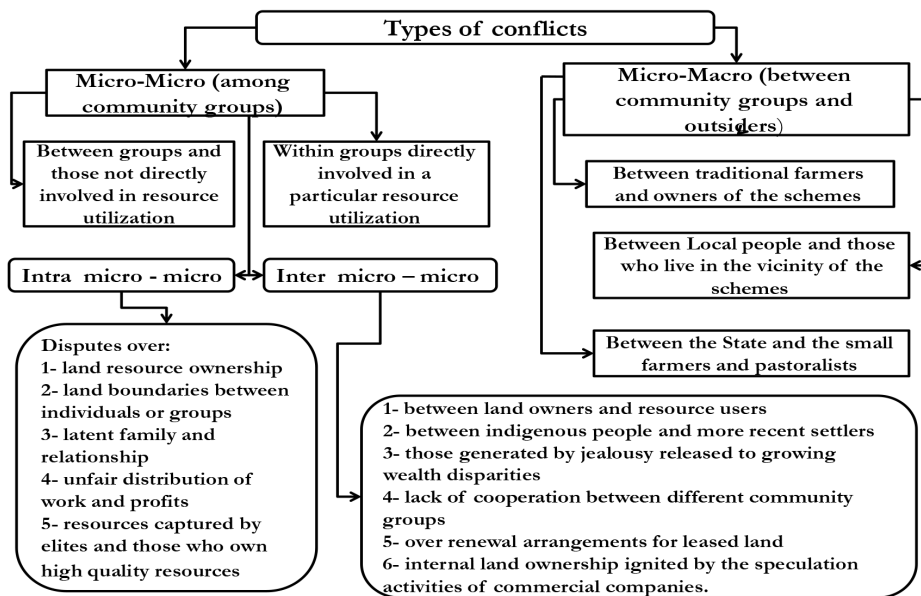


Figure.2: Modeling types of conflict in the study area

Micro-micro types of conflicts are further subdivided into intra and inter disputes. Intra disputes are those over land resource ownership, land boundaries between farmers and herders or their groups, latent family and relationship, unfair distribution of work and profits between farmers and landlords, resources captured by elites and those who own high quality resources who might be politicians, tribal leaders or businessmen. Inter types of conflicts include those between land owners and resource users, between indigenous people and more recent settlers, those generated by jealousy released to growing wealth disparities, lack of cooperation between different community groups, over renewal arrangements for leased land, internal land ownership ignited by the speculation activities of commercial companies. Types of micro-macro conflicts including the three sub groups outlined by figure (2) which are strongly linked with the micro-micro types of conflicts and their sub divisions which are fitting with our previous discussion.

Factors of conflicts

Factors considered responsible for natural resources-based conflicts in the study area include physical and human ones. Lack of water and pastures are the two major factors for direct conflict among farmers, grazers and herders (54%) and among local grazers and incoming herders (42%). The majority of the area's population indicated that conflicts are increasing during rainy season (41%) including months of June up to September, while only 4.5% indicated to after the rainy season period including October up to May. Lack of water and pastures are reflections of the type of the natural environment of the study area where geologic and climatic characteristics/or change are determining factors.

Most of the Gedarief area is underlain by Basement Complex of Tertiary Basalts both of which provide little water except in the detrital material around the occasional hills and small supplies to be found along joints in the rock. Basement complex rocks prohibit well digging and they are of low porosity and permeability which allow little or no water to penetrate downwards except along temporary water streams where the upper part of these rocks is weathered for few meters and is therefore porous. The underground supplies are not only small, but those at depth are extremely hard whilst the shallower ones are saline. Most of these water sources are temporal and linking with the rainy season where rainfall range is 300-900mm/year. Gedarief area has

two distinctive climatic belts. The first one is semi-arid climate found in the north and northwest and characterized by summer seasonal rains during July - October. The second one is a wet climate found in the eastern and southern parts with average rainfall of 500-900 mm/ year and maximum mean temperature of 47 °C. Rainfall in some major stations during 1994 recorded 777mm in Gedarief, 669.5 mm in Wd el Hourri and 616 mm in Gedambalia while it was 600 mm in Hawata (Meteorology Office-Gedarief, 1994). This closely related to rain variability in the Sahelian zone of Sudan.

Demographic aspects of the study area's population are also important into resource-based conflicts. The average family size is 8.9 with sex structure distributed as 49% males and 51% females. Economic reflections indicated that 75% of the populations are permanently staying in the study area while 25% of them have migrated to nearby Gedarief town (58%), Greater Khartoum (38%) and outside Sudan (4%). Reasons for migration included looking for work (60%), to collect money for marriage (28%) and education (12%). Incoming migration to Gedarief state numbered 746,714 in 1983 and reached 1,148,462 in 1993 with annual growth rate of 3.7% which exceeds 2.8% for whole Sudan. This is due to migrations seeking agricultural work, seasonal migration, natural increase and refugees inflowing from Ethiopia and Eritrea. Rural population was almost stable between 1983 (73.6%) and 1983 (73.7). The urban population increased from 22.7% in 1983 to 25% in 1993 that either the nomads became urban or rural became urban and the replace by nomads (MFEP, 1983-1993).

Major factors considered responsible for natural resources-based conflicts in the study area can be conceptually modeled (Fig.3) into four principal factors. The economy structure consists of mechanized and subsistence farming and traditional animal keeping are subject to climatic change and demographic factors; higher land demand and overpressure on the available infrastructure. The combination of demographic change and the limits to sustainable harvesting of renewable natural resources of forests, water bodies, grazing areas and agricultural land are often underlying cause of conflict over these natural resources, both among community groups, and between community groups and outside public and private resource utilizes in the study area. Mechanized agriculture has led to natural resources competition; developmental pressures; structural injustices, privatization of the economy

and bound with world market economies which are enhanced by governmental intervention. However, there are mutual interactions between types and factors of resource-based conflicts in the study area.

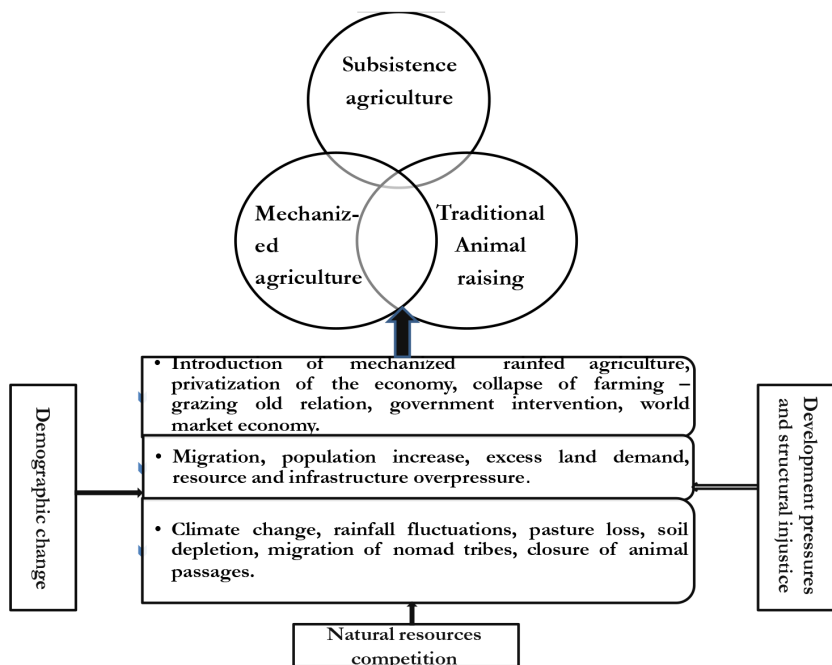


Figure 3: Factors of natural resource-based conflict in the study area

Discussion

The general findings of this study depict many types of conflicts taking place at various levels. There are conflicts among community groups and between community groups and outsiders who engaged into resource utilization in the study area. These conflicts were initiated between directly and not directly involved into resource utilization at the community base – level and furthermore, between community groups and outsiders (Figure 2). They were thoroughly affected by environmental factors, socioeconomic, demographic, development pressures and structural injustice caused by mechanized agriculture (Fig.3).

People of the study area used to live on self-subsistence economy, similar to African societies, prior to the introduction of extensive mechanized rainfed agriculture. The politicization of land ownership dates back to Sudan's

division by colonial administrators in 1923 into tribal homelands. The strong relationship between a tribe and its homeland has allowed the major tribes to use and monopolize the natural resources within their homeland and to deny minor tribes any claim to rights or ownership which would allow them to exercise political or administrative power.

The Colonial, post-World War II, Five –Year Development Program covering the period 1946 to 1951, considered mechanization of Dura production in Gedaref area a major success since it solved the problem of food shortage in African horn during war time. Therefore, the British were enthusiastic to expand mechanized agriculture in the Gedaref area irrespective of the negative impacts particularly that Gedaref area lies between the semi-arid zone and the rich savannah southwards. The direct negative impacts were the violation of tribal rights on land resource; cut of huge areas used to produce crops and hold animal to the modern mercantile agriculture; formed a barrier against herders' easy access to pastures and neglected rural societies of the study area who were left subject to rainfall fluctuations and impacts of droughts. This represents a kind of the effect internationalization of finance and trade is having on resource during that time when the British have invested huge money into mechanized agriculture to meet the demand for food in east Africa front against the Fascist and Reich, and later to mercantile traditional subsistence economy of the Gedaref area. The ultimate result, though positive results cannot be ignored, was the initiation of micro-micro and micro-macro types of conflicts among resource users there. From the early start, the division of land was unfair between landlords and local people in situation where problems of infrastructure were not solved and expansion into mechanized agriculture took place simultaneously with the import of machines and settlement of wage laborers who increased dramatically during the rainy season. This had caused pressure over resources, because the majority of the imported people were peasants or animal herders. In addition, the feelings of local people that they produce for landlords who gain much compared with farmers could be considered as latent factors for conflicts. This has been aggravated by climatic change, low soil fertility, deterioration and disappearance of natural vegetation, and loss of pastures.

The indirect role of Post Independence development policies in shaping conflict to natural resources was that, they have targeted development of the irrigated

agriculture in the clayey plains of central Sudan and neglected the traditional subsistence agriculture in western Sudan. The development program of 1957-1961, targeted the irrigated new extensions to the Gezira scheme which was established by the British in 1925 to produce cotton for export and further considered building new dams to bring more land under irrigated cultivation and the building of sugar factories and sugar plantations. There was a phenomenal increase in private pump schemes for cotton production along the Blue and White Niles. The Ten-Year Plan of 1961/62 -1970/71 also recommended the extension and crop intensification in the Gezira and development of new pump schemes on the Blue and White Niles which altogether increased the irrigated area by 1700000 feddans (MFEP, 1961). The share of the study area from this Plan is reflected in the number of the tractors which increased from 2040 to 8000 and combined harvesters in use from 120 to 700 (Lees et al., 1977). The Seven Year Plan, 1970/71-1976/77 emphasized on proposing new irrigated schemes in central Sudan. Flood irrigation was to be substituted by gravity irrigation in Northern Province. Rural development projects included settlement of nomads. Conflicts over land were further politicized by the 1970 Unregistered Lands Act which enabled the government to implement a development policy based on the expansion of the agricultural sector, especially mechanized farming. The legislation had given the government the right to use force to safeguard "its" land, and to encourage the accumulation of land by minority of rich local and foreign investors. This alienated agro-pastoralists from their traditional homelands, denied any formal legitimacy or juridical status to traditional property rights, and implied the cancellation of all rights - and income - relating to water, land and grazing by pastoralists. The six-year plan, 1977/8 – 1982/3, and later replaced by the Three-Year Investment program up to 1983, proposed the development of subsistence agricultural sector and conservation of Sudan's natural resources. The neglect of the traditional subsistence agriculture has driven the farmers involved in that sector to migrate to the more developed areas in central Sudan and to compete with population living there over available resources. The Gedaref area is not exceptional where in addition to migration, landlords of mechanized farms had brought seasonal and wage workers from western Sudan and West Africa.

These conflicts could be situated within the current government policy of governance which was launched with the National Economic Salvation

Program, 1990 -1993. This program had implied more emphasis on agricultural development and export-oriented policies through liberalization. It also tended to encourage agricultural credit through special fund and exclusion of all bank credit to agriculture and animal production from credit ceiling. The 1990 Investment Act have allocated vast tracts of land to private capital investments by which substantially cutting rural communities' rights to land and dislocating people from their homeland. This government policy is still continuing adopting privatization of public sector agricultural schemes, commercialization and lift of subsidy to agriculture which lastly brought foreign capital investment to this sector. The adverse effects are the sealing off nomadic routes, water points and pastures, fostering a culture of land-grabbing and creating large landless groups who are forced to work as precarious wage laborers or to migrate elsewhere. The establishment of Gedarief Bourse was to further mercantile agricultural produce where the resident representative of Banks, Companies and wealthiest individuals are controlling their business from Khartoum.

These types of conflict in the study area are similar to those in sub-Saharan Africa in general, where population growth and increasing commodity production have led to the expansion of agriculture on formerly shared grazing lands, and have increased conflicts between these groups (Fratkin, 1997; Tatlock, 2006), and also similar to West African sub-region; southern Ethiopia, Northern Kenya and Somalia (Mekonnen, 2006). The factors of resource – based conflict in our example is also similar to many places in Sudan, where conflicts over resources are often escalated by high year-to-year variability in rainfall which leads to extreme seasonality and irregular distribution of rainfall over the year (Elagib, 2010), (Hulme,1990), population increase and the state policies (Ayoub, 2006) and over water and grazing rights as in Darfur (Schanche, 2007). It also agrees with Suliman's study (1994) that the ecological and social stress caused by large-scale mechanized agriculture in eastern Sudan can be held responsible for conflicts (Suliman, 1994). However, it differs than the conflict in southern Sudan which was basically ethnical (ebow.com, 2011), or that caused by cultural or ethnical beliefs as in Nigeria and South Africa (Irobi, 2005) or southern Ethiopia (Assefa, 2011). It also differs than those occurred in Sierra Leone (Nnane, 2007) and Angola and Chad (le Billon 2010) which were indicated in the introduction of this paper.

Conclusions and recommendations

1. There are micro-micro and micro-macro types of conflicts.
2. Factors considered responsible for conflicts in the study area include natural resources competition ; developmental pressures; structural injustices caused by mechanized agriculture and demographic change.
3. Globalization and world market economies impact on at subsistent farmers level.
4. These conflicts are similar to others occurring in the Sahelian zone and in Sudan.
5. These conflicts are threatening the relation between human, environment and resource utilization.

Conflicts in the study area are particularly vital for a conflict riddled country like Sudan where resource-based conflicts have imperatively affected rural societies. Some scholars have proposed solutions for natural resources-based conflicts. One example is that by Mekonnen (2006) who recommended the building of an early warning system that should be adopted at local, national, and regional levels for mitigating impacts of drought, famine and conflict. In this study, Triangle of Environmental Surveillance was proposed by the author (Fig. 4). It consists of a hierarchical structure of three interrelated axes including human, environment and resource utilization. Human inherited experience and traditional knowledge on agriculture and grazing and coping mechanisms, for example, could benefit here. Environmental holding capacity should be considered in order to keep on sustainability while resource utilization should match with this environmental capacity and make benefit from inherited experience and culture of the people of the study area.

Based on the results outlined in figures 2 and 3, the proposed triangle of environmental surveillance focuses on curbing natural resources-based conflict by caring the human first. Provision of community-based knowledge is essential. This knowledge should cover aspects of respecting others' rights in accordance to the type of resource utilized, strengthening and empowering traditional conflict resolving mechanism, contributes to building relationship among and across communities which diminishes the frequency and intensity

of conflict, and encourages cooperative solutions to other problems. Building capacity of the institutions of the nomads including traditional administrative systems; culture of raising animals; and use of water points; mobility in search for pasture and knowledge sharing will make these communities more aware on misuse of resource utilizations and their impacts. Basic agricultural schools will teach farmers on how to use modern agricultural practices, appropriate use of water and soil, adaptation with climatic change and knowledge sharing among themselves and with others. Addressing specific needs of local populations, enhancing local knowledge and skills, building the capacity and preparation of traditional mechanisms for combating drought are essential. They include collecting/harvesting rainwater in man-made ponds, diversifying grazing lands, and planting trees that adapt to dry climates.

Rehabilitation of degraded rangelands, reserve of green belts, rainfall database, and permanent water points are major axes for the environment sustainability in our model. Rehabilitation of degraded rangeland will keep on recent use and increases its future holding capacity. Research on drought and desertification by identifying causal natural and human factors is essential where the role of official authorities is remarkable either by monitoring or aware of people. Reserves of green belts will aware people to respect natural resources in order to respect others' rights on resources. Rainfall database will provide information for the agricultural season, expected pasture, locations for good agricultural production and vulnerable areas to crop failure and expected food shortage in order to avoid excess use by farmers or herders. Permanent water points have to be in accordance with rainfall database and population density taking into consideration the physical characteristics of the study area.

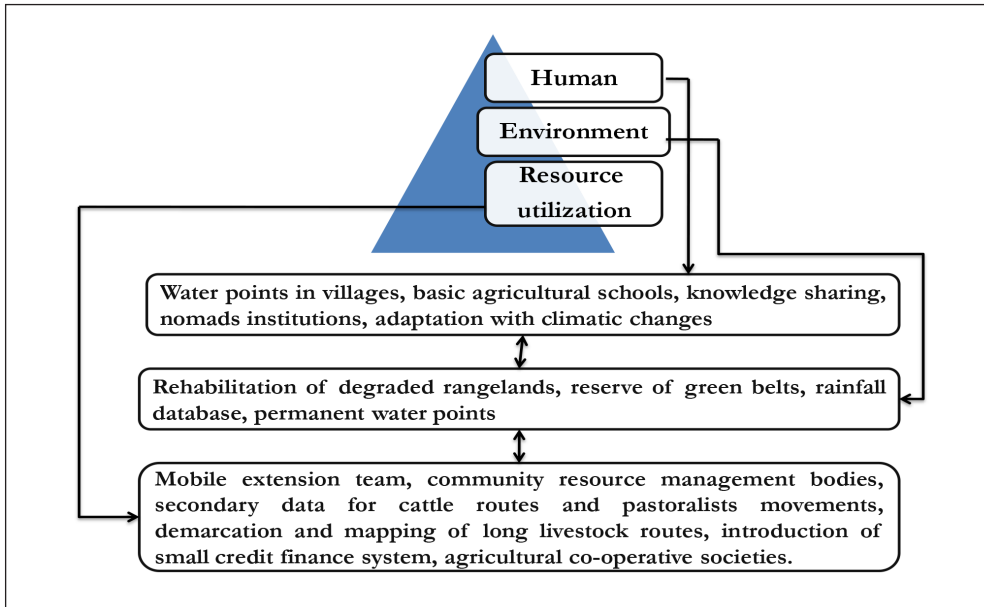


Figure 4: Triangle of environmental surveillance for reduction of resource-based conflict in eastern Sudan

Resource Utilization included mobile extension team, community resource management bodies, secondary data for cattle routes and pastoralists movements, participatory demarcation with concrete posts for livestock routes and conflict prevention, mapping of long livestock routes. In addition, maps and secondary data for cattle routes and pastoralists movement should be introduced with local patrolling team comprising representatives of pastoralists, farmers, native administration and the old system of pastoralists. Protected animal resources could be through provision of veterinary drugs and vaccines and equipment and establishment of veterinary service pharmacies at wet grazing.

Introduction of small credit finance system, agricultural co-operative societies, opening of fire lines are also parts of natural resources management. Empowering farmers and pastoralists institutions to strengthen their capacity to understand tenure rights, knowledge sharing on natural resources management and conflict resolution and legal awareness about land tenure and conflict are also essential. In addition, trained local mediators in natural resources management and conflict resolution, establishment of networks

including farmers and herders for building partnerships between pastoralists and farmers, and between pastoralists and local government are also vital.

Managing relationship between man, the environment and resource utilization have to be introduced into Sudanese planning in order to curb tribal conflicts and to keep the entity of the country. This is important as civil wars in southern, western and eastern Sudan are ignited by issues of marginalization, lack of development and infrastructure and southern Sudan is now on the road for separation. However, understanding how communities access natural resources and tensions and rivalries entailed in this process is critical not only for discerning livelihood systems, but can also inform sustainable development policy in Sudan. Although the word 'conflict' is often thought of as the opposite of co-operation and peace, it can often be seen as a force for positive social change, its presence being a visible demonstration of society adapting to a new political, economic or physical environment.

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8

Potentialities of Hydro- Geomorphic Characteristics of Gash Valley for Rural Development in Red Sea Area

Potentialities of Hydro-Geomorphic Characteristics of Gash Valley for Rural Development in Red Sea Area

Sudan is virtually striving to optimize its natural resources to speed on economic growth, ease political instability, and enhance population growth and to step into the millennium. These natural resources are varied, among which are the seasonal valleys which own abundant amounts of annually discharged waters. These valleys are mostly of mountainous origin, flashy with extremely high discharge, and are sources of disaster vulnerability. Their hydrological behaviors are controlled by their own geomorphic characteristics and nature of precipitation. ‘Their hydrologic regime is characterized by high variability in temporal and spatial rainfall distributions, flash floods, absence of base flow in most cases, and high rates of evapotranspiration’ (Aboubaker et al. 2019). This research aimed to show these characteristics, as exemplified by Gash, in order to build for rural development in semi-arid Red Sea area via water harvesting programs and reduction of flood disasters.

Rainfall events in semi-arid areas are in general of short duration and high intensity and often characterized by a large degree of spatial heterogeneity (Pilgrim et al., 1988; Wheeler et al., 1991; Martinez-Mena et al., 1998; Lázaro et al., 2001; Wheeler, 2008). These characteristics are even more pronounced in regions with topographic complexity such as mountain ranges (Wilson et al. 2004). Due to the spatial variability of rainfall, runoff is frequently localized while runoff generated in some parts of the catchment may later re-infiltrate and thus do not contribute to runoff at the outlet of the catchment. Runoff may re-infiltrate in the bottom of a valley into a bed of alluvial sediments or become overland flow that may be lost as infiltration into fractured bedrock of channels (Hughes 1995). The infiltrating discharge water contributes to groundwater recharge and the associated groundwater flow in the river valley sediments.

River discharge is the final outcome of a large number of vertical and horizontal flow processes within the whole catchment of the discharge observation point. In semi-arid regions the characteristics of the river flow can be classified as perennial that is flowing all the year; seasonal where flowing only occur in part of the year or ephemeral with extreme flow variability ranging from no flow to flash flood during storms (Lerner et al., 1990). In this region also, discharge appearing in the upstream parts of the river system

may gradually diminish during migration in the river system. This is due to infiltration into the river bed and eventually the flow in the river may disappear completely. Also, overland flow in semi-arid areas is categorized into, Hortonian-type of runoff and saturation excess overland flow type, according to the mechanisms responsible for its generation. In the Hortonian-type of runoff high rainfall events exceed the infiltration capacity of the soil and thus leads to surface runoff. (Pilgrim et al. 1988, Hughes 1995). The other type of overland flow occurs when rain falls on land where the subsurface is saturated, which may arise during a rainy period in the bottom of the valley. Another common characteristic is that discharge appearing in the upstream parts of the river system may gradually diminish during migration in the river system due to infiltration into the river bed and eventually the flow in the river may disappear completely. Only during flash floods the river may discharge to the sea. This is particularly true for semi-arid regions where recharge may be as low as 1% of the precipitation (Bouwer, 1989). Furthermore, recharge usually only occurs in limited areas and generally it is non-existent or negligible over much of the semi-arid landscape e.g., at hill slopes. Recharge may occur by various mechanisms, mainly as direct infiltration in flat areas or infiltration from river beds. Additionally, in some formations the excess precipitation is subsequently routed through fractures before discharging into the river or the alluvial material of the lower plains. Finally, the infiltration capacity is also high around vegetation, and conversely, vegetation may only grow where the infiltration capacity is relatively high (Pilgrim et al., 1988).

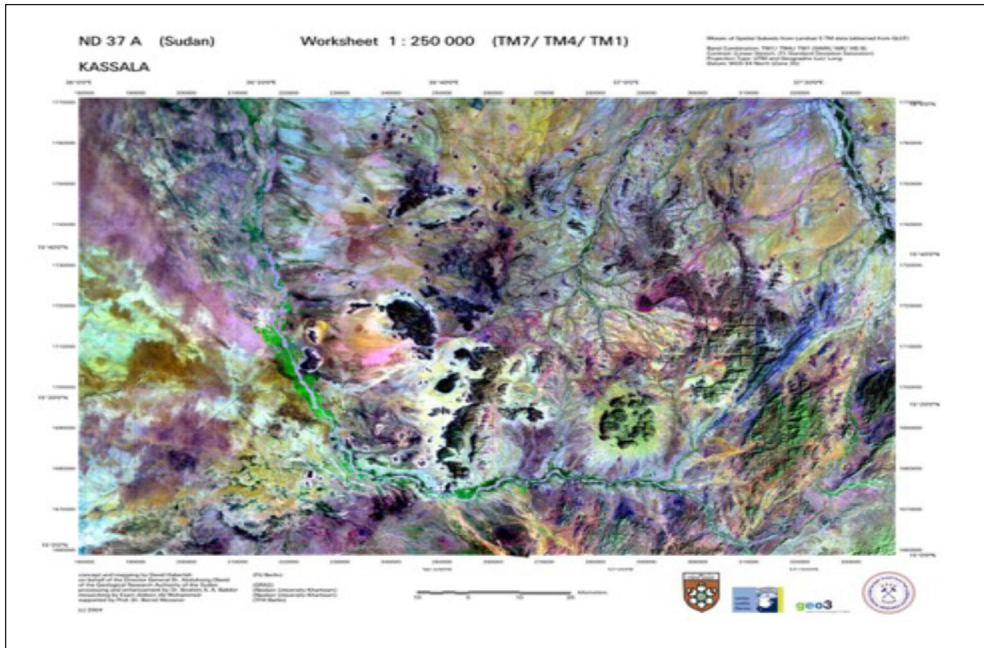
Evapotranspiration is controlled by several factors such as meteorological conditions; characteristics of the surface; canopy; and soil characteristics. In semi-arid regions also, evaporation from bare soil assumes a greater importance relative to transpiration from plants, due to the larger area of bare soil and the frequency of small rainfall events which allow bare soil to return water to the atmosphere without major pathway impedance (Pilgrim et al. 1988). In such regions evapotranspiration captures most of the water entering the soil, and recharge occurs only at extreme rainfall events (Pilgrim et al., 1988). As a result of the spatial variability of landscape characteristics such as geology, topography, soils, land use and vegetation, evapotranspiration will likewise exhibit a spatial variation (Güntner et al. 2004). For hilly and mountainous catchments with a relatively sparse vegetation cover and subject to high rainfall intensities overland flow generation is frequently

occurring (Wheater, 2008). This region's recharge of aquifers may be as low as 1% of the precipitation (Bouwer 1989) and usually occurs in limited areas and generally it is non-existent or negligible over much of the semi-arid landscape.

In semi-arid and arid areas, rain water and flood water harvesting came up in interest in recent decades due to insufficient sources of pumped ground water, reservoirs and streams to meet human and animal demand for water (Prinz 2002). Water harvesting techniques harvest and concentrate rainwater and consequently could increase soil moisture and yields (Mugabe 2004). Infield water harvesting for improved crop yield in semi-arid regions of Zimbabwe has been used to adapt to changing climate since climate change increased vulnerability of crop failure in such areas (Nyamadzawo et al. 2013). In semi-arid Southern African Development Community which is overpopulated and environmentally fragile there are a number of traditional and new and adapted techniques for water harvesting which aim to alleviate the limiting crop production factors (Kronen 1994). In India, several techniques of water harvesting are used in its semi-arid parts for centuries to protect water supplies and to increase agricultural production, and they have been recently promoted (Batchelor et al. 2002).

Location of Gash valley and data sources and methods

Gash valley, located at 36° 15' - 36° 30' E, and 15° 15' – 15° 45' N, is a seasonal stream (valley) flowing from late June to October and originates in the Eritrean highlands (Figure1). When entering the Sudan, the Gash changes from a westerly direction to northerly direction and attains its characteristically appearance of a wide shallow stream with a sandy bed and extensive flood plains on either side as far as el Sabeel/ Wad Sherefei where north of that the Gash Valley tends to widen and further north it fans out into an inland delta (ELKirail et al. 2008).



*Figure 1: satellite image of Gash valleys showing source, direction and delta
Source: GRAS, Geological Research Authority of Sudan, 2010*

The satellite image (Figure 1) provided by Geological Research Authority of Sudan (ND 73 A- Sudan Worksheet 1:250000 TM7/TM4 TM1) was interpreted to obtain some of the Gash valley's geomorphic characteristics. Hydrologic data for Gash's was obtained from Ground Water and Valley Directorate and relevant fieldwork carried out by TNO-DGV et al. (1982). Studies on channel fill and sheet flood facies sequences in the Gash valley were from Abdullatif's research (1989), and data on regional ground water flow of Gash were from Elkirail et al. (2008), while data on ground budget were from El Tom et al (2010) and were used to obtain hydrologic and ground water data for Gash. A recent satellite image of Gash valley, based on DEM 90 USGS was processed by GIS Arc-Map 10.5 to produce ordering of Gash's basin.

Geomorphological characteristics of the Gash Valley

The basement complex represents the oldest rock units in Gash Valley area. The area is then subjected to a period of extensive erosion that reduced the area to a peneplain. The main outcrops of the basement are the granitic biotitic gneisses of sedimentary origin of J. Kassala, and J. Mukram which

rise on the plain, and in other places the basement complex was covered with Tertiary-Quaternary deposits (ELKirail et al. 2008). The Gash valley's total catchment area is about 21000 km². In width it varies between 100 m and 800 m. The flood plains may attain a width of as much as 1,000 m on either side of the river bed. Topography is flat to slightly rolling in the Gash-delta, with a gentle sloping towards the north-west. Elevation is a little more than 500 m above mean sea level in the south-east to less than 450 m above mean sea level in the north-west. Just east of Kassala town the topographical features are dominated by two mainly north-south oriented inselbergs of which Jebel Kassala, with an elevation of 1,346 m above mean sea level forms the highest top. The Gash valley basin is filled by the Quaternary alluvial deposits, unconformably overlying the basement rocks. The alluvial deposits are composed mainly of unconsolidated layers of gravel, sand, silt, and clays. The clay of the plain overlies the basement complex, Cretaceous sedimentary series and Tertiary lavas. Detailed facies analysis of the River Gash fluvial sediments has revealed a channel-fill and sheet-flood sequences. It seems that each sequence type is produced by specific depositional event, and both sequences represent two-end members for group of mixed sequences. The facies and sequences show rapid lateral variability, and they merge and interfinger with each other. They also show partial to complete modification due to subsequent floods and stage variation.

The clay of the plain is usually found above the river flood plain east and west of alluvial deposits. It consists of laminated loose to compacted clay, silt and sandy silt. Its thickness ranges from few meters to about 20 meters along the west side of alluvial deposits. The alluvial deposits were formed by the action of Gash Valley during the flood seasons. The coarse material of sand and gravel deposits are located upstream and the finer material of clay deposits downstream. The thickness of alluvial deposits upstream is about 30 meters and reach up to 70 meters downstream. They are composed of intercalating beds of unconsolidated coarse to fine-grained gravel, sand, silt and clay. The gravel is composed mostly of angular to subangular quartz pebbles; however, the volcanic, felspathic and granitic gravels are present. The sand is mostly composed of quartz; however, felspathic micaceous and volcanic sand are present. The aquifer is unconfined and is laterally bounded by the impermeable Neogene clays (Eltom et al. 2010). The Gash aquifer is composed of heterogeneous sequence of layers which is dominated by coarse sand,

gravel, clayey sand and silts (El-Krail et al. 2008).

Gash valley stream ordering (Figure3) reflects an operating dendritic network in the upper and lower reaching. First order and second order have formed on steep slopes of mountains in Eritrea (Ethiopian plateau). They are the headwater valleys, and also, could include third order valleys as headwater streams. Fourth order could be medium valleys, characterized by less steep and flow more slowly, but tend to have larger volumes of runoff and debris as it collects them from the smaller waterways flowing into them.

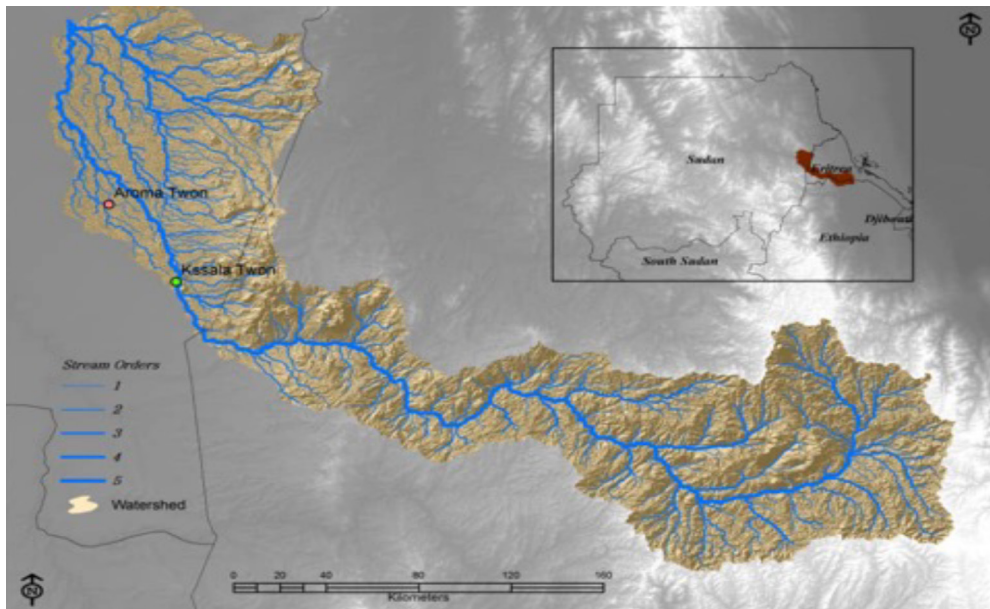


Figure3: Gash ordering
Source: GIS Arc-Map 10.5 based on DEM 90 USGS

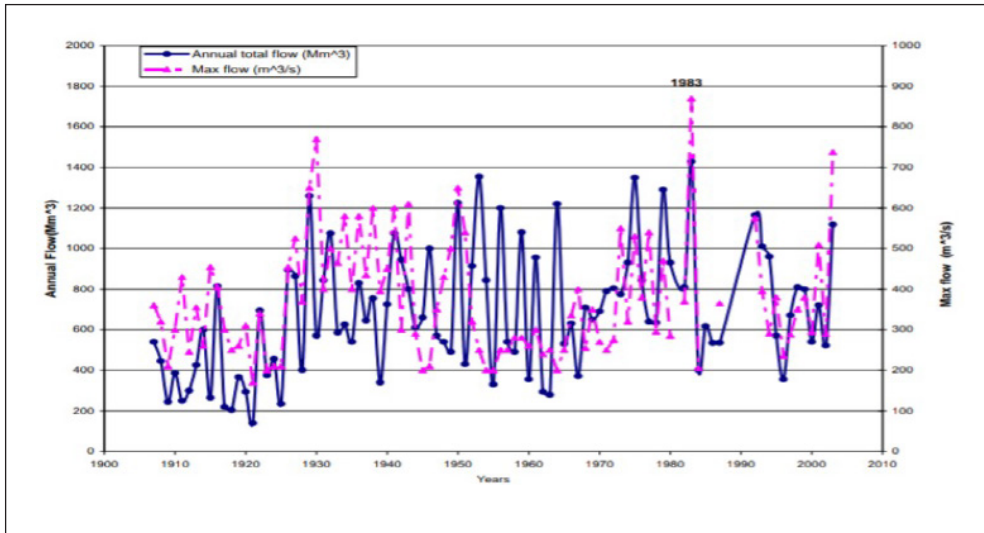
Rainfall characteristics over Gsh valley

Gash valley lies within semi-arid climate of Sudan, with moderate amounts of rainfall during summer season. Nyala valley lies within belt of wet-climate in Sudan with abundant rainfall amounts during summer season. The I.T.C.Z which brings wet southwest winds over the Sudan influences both valleys' rainfall amounts. The Indian Ocean influences the climate of the Ethiopian plateau and the interior of the Sudan where in several years abundant rainfall amounts were observed over the Ethiopian plateau and southern Darfur.

Rainfall was locally heavy (> 75 mm) in Southern Darfur regions of Sudan and abundant amounts of rain (> 100 mm) fell across the highlands regions of Ethiopia. These rains have kept river water levels elevated to or near flood level for the Blue and White Nile, Atbara River and Gash River (USAID 2010). The area including Gash valley indicates to a fewer rainfall amounts compared to that of Nyala valley's. Abundance rainfalls over the Ethiopian plateau influence the final budget of water of Gash's, while the Nyala valley's catchment area is determined and governed mainly by the local thunderstorms, which are usually travelling across the area from north-east to south-west. The storms usually cover only part of the catchment area, but the high intensity of the rains still generate considerable volumes of surface runoff.

Hydrologic behavior of the Gash Valley

The discharge measurements of the Gash River, which go back to 1907 (Figure 6), are showing high fluctuation. The minimum annual total discharge is 140 million m^3 , which was recorded in 1921, while the maximum annual discharge is 1430 million m^3 recorded in 1983. It should be noted that year 1983 represents the year before the peak of the drought in 1984, which stroke the whole African countries during the eighties, in particularly Ethiopia and Sudan. It is clear that the maximum annual flow is almost 10 times the minimum one, indicating the high variability of the flows in Gash River. However, the minimum instantaneous discharge is $170 m^3/s$ in 1921 and the maximum one is $870 m^3/s$ in 1983. The flow in the Gash Valley can start with only trickle move and reaches more than $850 m^3/s$ in very short time (Figure 7). The annual average flow is 680 million m^3 (Bashar 2011), while the average annual discharge of the Gash Valley is estimated to be $1,056 \times 10^6 m^3$ at El Gera gage station (upstream) and $587 \times 10^6 m^3$ at Salam-Alikum gage station (downstream). The annual water loss mounts up to 40% of the total discharge which is attributed to infiltration and evapotranspiration.



*Figure 7: Annual Total and Annual Maximum Flow Series of Gash River
Source: Bashar (2011)*

The groundwater input reaches $386.11 \times 10^6 \text{ m}^3/\text{year}$, while the groundwater output is calculated as $365.98 \times 10^6 \text{ m}^3/\text{year}$. The estimated difference between the input and output water quantities in the upper and middle parts of the Gash Valley demonstrates a positive groundwater budget by about $20 \times 10^6 \text{ m}^3/\text{year}$ (Eltom et al. 2010). Hydraulic conductivity ranges from 36 to 105 m/day, whereas the transmissivity ranges from 328 to 1,677 m^2/day . The monitoring of groundwater level measurements indicates that the water table rises during the rainy season by 9 m in the upstream and 6 m in the midstream areas. The storage capacity of the upper and middle parts of the Gash valley is calculated as $502 \times 10^6 \text{ m}^3$. The average saturated thickness varies from 20-35 m. The predominance of sheet-flood deposits is consistent with the ephemeral flashy high flow regime in the Gash Valley. The recharge of aquifer is due to infiltration from the Gash Valley during flood seasons or direct precipitation from the rainfall. The general flow direction is towards the northwest (ELKirail et al. 2008). The infiltration capacity of the soil is low, due to the presence of a resistance surface soil cap. Soon after rain starts, the heavy impact of the raindrops closes the soil surface almost completely, by the forming of a thin layer pan or cap.

Discussion

Gash valley is of mountainous origin, flashy with high discharge initiated by similar rainfall influences. It is an integral part of the network of Sudanese rivers and valleys (DIU 2009). Sudan is an agricultural country with huge fertile lands and strives to optimize utilization of its share of Nile Water Agreement with Egypt to achieve and accelerate development in riverain areas of central and northern Sudan where Gas and Kassala areas are at a distance. Alternative development efforts could target developing and promoting water harvesting of Gas valley to provide huge amounts of water that might exceed some areas close to the Niles. It would participate into developing water sources outside the Nile areas, reducing poverty of rural communities, enhancing agro-animal production through provisioning of quality water, conserving and protecting the environment, enhancing national security and promoting peace and settlement by developing border areas and reducing water related conflicts throughout Sudan and neighboring countries, increasing per capita share of home water in line with the State's strategy in supplying quality water with sufficient quantity. Gash valley could specifically contribute into settlement of nomads to evade their conflict with peasants, and encourage refugees and internally displaced peoples to return home (DIU 2009). This is particularly significant since the area of Gash valley is characterized by climatic conditions conducive to water shortage which had seriously caused many dramatic changes by disturbing the rhythms of grazing, cultivation, and migration and so compete with livestock for both land and water (Alredaisy 2012).

The Gash valley is a factual part of areas of tribal and militant conflicts in Sudan. The East Front fought the Ingaz Government for decades. The initiation of tribal conflicts, prior to their politicalization, was environmentally based on shear water resources during the dry season. Implementation of water harvesting programs based on hydrological potentialities of Gsh valley could provide reliable sources of water for rural communities and support the State's policy to achieve Eastern Sudan comprehensive peace" (DIU 2009). It is expected that the Gash valley in Eastern Sudan, to engine targeting collecting rain water or "seizure" of flowing water during the rainy season during December- June for human and animals announced by Water Harvesting Programs of Sudan. This is important under the scenario of

climate change and related anthropogenic effects in the Sahelian zone of Sudan where Kassala and Nyala areas are part of that zone. Under this climate change conditions, shortage in water production is expected, which will be more exacerbated by increasing human and animal demands. This is important to put into consideration with World Health Organization (WHO 1983) of daily allocation of per capita water, but the inclusion of animal population gives a different scene of water shortage.

Areas of eastern Sudan had witnessed onsets of desertification as it has been designated by the United Nations as under “very high risk” of desertification (UN 1977), desert encroachment, and threat from sand creep and have been affected by changing characteristics of the rainy season since early sixties (Zeng 2003). The rainfall records of many gauge stations suggest a long-term average annual rainfall of 285 mm (1902-1990), and since the 1950s the average rainfall has fallen sharply due to severe drought from 1968 to 1972 and again in the 1980s, with 1984 being the driest year on record. The mean rainfall for 1965-84 was 214 mm, 40% lower than the 365 mm seen from 1920-39 (Walsh 1991). The decade 1981-90 was 35% below the mean of 330 mm for 1920-50. Based upon available figures there seems to be little evidence for significant improvement since 1990 (Alredaisy and Davies 2000). Rainfall figures in the 20th century suggest that the 1930s saw a peak in rainfall and that since then rainfall was generally in decline until the mid-1970s, when it appears to have leveled out at about 250 mm. These areas also face problems of global warming, rapid increase of human and animal population as manifested by deterioration of natural vegetation (Davies 1987). In such marginal lands of Kassala, water insecure groups of the Sudan are found, who are usually poor and self-provisioning producers (Green 1989, Knerr 1998) and are pushed by land hunger into ever more marginal lands in term of weather, soil and ecological fragility (Alredaisy and Davies 2001).

The importance of water harvesting of Gash valley could extend to include reduction and management of urban disaster for Kassala central-regional town which is extremely vulnerable to flashy annual floods which caused damages and sometimes lead to population displacement (Alredaisy 2011). Urban disaster management and reduction strategy for both of them, the inclusion of the concept of regional flood vulnerability is a necessary

perquisite. It concerns with the capacity to resist flood of all kinds of disaster bearers at a region, and includes indicators of disaster environment, disaster drivers, disaster bearers, and disaster bearing capacity of society (GAO et al 2004). Comprehensive evaluation of urban disaster reduction management is important prerequisites for improving the level of urban disaster reduction management in Kassala town. Following the future strategies of world disaster reduction in 2005, it could be more effective. These strategies, which are a core task of regional sustainable development, include “construction of community disaster-reduction system, combining disaster reduction with regional development to seek the sustainable development way and to build up safer community systems which can accept some certain risk level. It is important to establish warning systems, accelerate to share disaster reduction information and make full use of the existing disaster reduction resources in order to establish a social-economic system which can coexist with disaster risks well (Shi et al. 2005).

Conclusions and recommendations

1. Geomorphological characteristics of Gash valley shows its mountainous origin and is influenced by the Intertropical convergence Zone (ITCZ) and Indian Ocean monsoons which initiate its annual flooding.
2. Gash valley is flashy with huge annual discharge with distinctive hydrological behavior.
3. It is a source of disaster vulnerability to Kassala and Nyala regional towns and their geographic neighborhood.
4. It is proficiently potential to contribute into rural community development in semi-arid Sudan in the course of appropriate water harvesting programs. This could eventually reduce vulnerability to flood disasters in their geographic neighborhoods.

The optimization of hydro-geomorphic characteristics for water harvesting and disaster management of Gash valley to induce rural community development, drives for recommendation of the improvement of hydrological recording and geomorphic controls on hydrology at the scale of Gash valley and at the scale of their physiographic regions. This is important since geomorphology exerts both direct and indirect controls on the pattern, timing

and volume of runoff generated within a basin. At the scale of physiographic regions, the natural flow regime of Gash valley is determined by the broad scale interaction between geology and climate which establishes the overall pattern of annual runoff, drainage network structure and the longitudinal organization of the two valleys drainage. This is important since will determine the timing and rate of runoff for individual storm events, which are necessary for disaster management. Improvement of spatial estimates of precipitation for water harvesting and disaster management is also important. They could be computed from point measurements using well established spatial interpolation techniques. Also, estimating the spatial and temporal distribution of runoff entering the two valleys' system during a storm event is important to the understanding of the physical dynamics of catchment hydrology (Refsgaard et al. 1995). This is beside recharge estimates including physical, chemical or numerical modeling methods (Lerner et al., 1990; Scanlon et al. 2007), and flow rate estimates or water level in the channel system by using one-dimensional modeling system (Havnø et al. 1995).

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